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POLLUTION OF THE INTERSTATE WATERS OF THE COLORADO RIVER AND ITS TRIBUTARIES, COLORADO, NEW MEXICO, ARIZONA, CALIFORNIA, NEVADA, WYOMING, UTAH. PROCEEDINGS OF CONFERENCE, SESSION (7TH) HELD AT LAS VEGAS, NEVADA ON FEBRUARY 15-17, 1972. VOLUME 2

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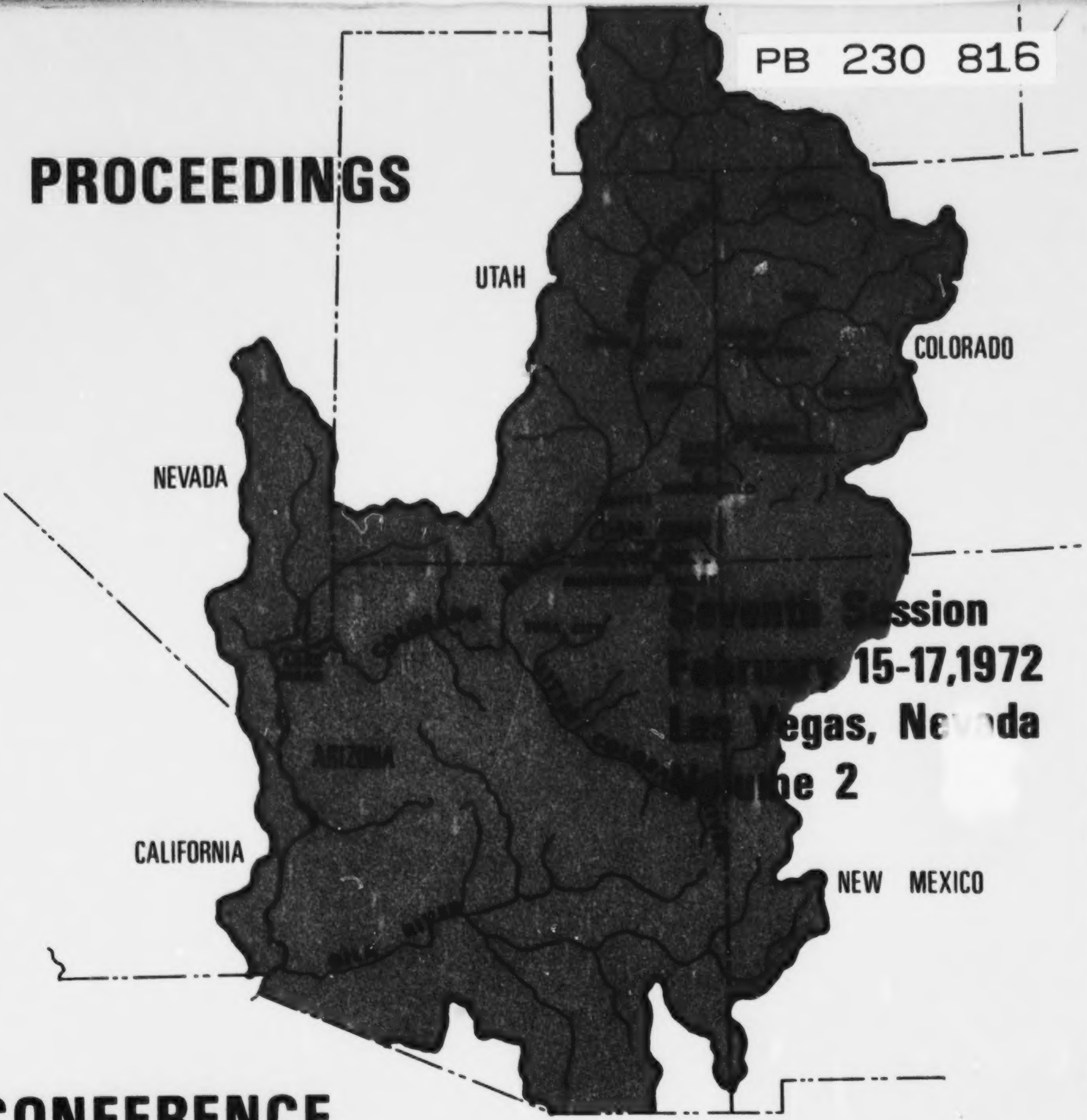
UTAH
COLORADO
NEVADA
ARIZONA
CALIFORNIA
NEW MEXICO

Seventh Session
February 15-17,1972
Las Vegas, Nevada
Volume 2

CONFERENCE

In the Matter of Pollution of the Interstate Waters of the Colorado River and its Tributaries - Colorado, New Mexico, Arizona, California, Nevada, Wyoming, Utah.

ENVIRONMENTAL PROTECTION AGENCY

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SEVENTH SESSION OF THE CONFERENCE IN THE MATTER OF POLLUTION OF THE INTERSTATE WATERS OF THE COLORADO RIVER AND ITS TRIBUTARIES - COLORADO, NEW MEXICO, ARIZONA, CALIFORNIA, NEVADA, WYOMING AND UTAH

held at

Las Vegas, Nevada
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TRANSCRIPT OF PROCEEDINGS

VOLUME II

R. Freeman

MR. FREEMAN: The Colorado River Basin Water Quality Control Project was established as a result of recommendations made at the first session of the joint State-Federal Conference in the Matter of Pollution of the Interstate Waters of the Colorado River and its Tributaries. This session was held in January 1960 under authority of Section 8 of the Federal Water Pollution Control Act, as the Chairman has already explained. The conference was called at the request of the States of Arizona, California, Colorado, Nevada, New Mexico, and Utah to consider all types of water pollution in the Colorado River Basin. The project serves as the technical arm of the conference and provides the conferees with detailed information on water uses, the nature and extent of pollution problems and their effects on water uses, and with recommended measures to control pollution in the Colorado River Basin.

The Environmental Protection Agency was established by Reorganization Plan No. 3 of 1970 and became operative on December 2, 1970. EPA consolidates in one agency Federal control programs involving air and water pollution, solid waste management, pesticides, radiation and noise. This report was prepared over a period of 8 years by water program components of EPA and their predecessor agencies, those being the Federal Water Quality Administration of the U. S. Department of the

Interior, the Federal Water Pollution Control Administration of the U. S. Department of the Interior, and the Division of Water Supply and Pollution Control of the U. S. Public Health Service. Throughout the report one or more of these agencies may be mentioned and these should be considered as part of a single agency in evolution.

MR. STEIN: Say, Russ, will you slow up a little?

MR. FREEMAN: Yes, sir.

MR. STEIN: Thank you.

MR. FREEMAN: The project has carried out extensive field investigations along with detailed engineering and economic studies to accomplish the following objectives.

For those who wish to follow in the report, I am reading now from the introduction.

The first objective: to determine the location, magnitude, and causes of interstate pollution of the Colorado River and its tributaries. The findings with regard to this part of the report will be presented by Mr. Blackman later.

The second objective was to determine and evaluate the nature and magnitude of damages to water users caused by various types of pollution. And these findings will be presented by Mr. Jim Russell.

The third objective was to develop, evaluate, and recommend measures and programs for controlling or minimizing interstate water pollution problems. And our recommendations here will be discussed by Mr. Jim Vincent.

In 1963, based upon recommendations of the conferees, the project began detailed studies of the mineral quality problem. Mineral quality, which is commonly known as salinity, is a complex basinwide problem and it is becoming increasingly important to users of Colorado River water. Due to the nature, extent, and impact of the salinity problem, the project has extended its activities over the entire Colorado River Basin and the southern California water service area.

The basin, for those of you not familiar with it, is shown on the map and the outlines of the seven basin States are included.

The more significant findings and data from the project's salinity studies and related pertinent information are summarized in the report which we are presenting this morning. This report consists of a summary document and four appendices. The first appendix describes natural and manmade conditions affecting mineral quality. Appendix B describes the physical and economic impacts. Appendix C describes salinity control and management aspects. And Appendix D contains the comments of various State agencies upon a draft report which was submitted for their review.

The Colorado River is situated in the southwestern United States and extends 1,400 miles from the Continental Divide in the Rocky Mountains of north central Colorado to the Gulf of California. Its river basin covers an area of 244,000 square miles or approximately one-twelfth of the continental United States. The Colorado River Basin includes parts of seven States: Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming. About 1 percent of the basin drains lands in Mexico.

The Colorado River rises on the east slope of Mount Richthofen, a peak on the Continental Divide having an altitude of 13,000 feet, and it flows generally southwestward, leaving the United States at an elevation of about 100 feet above sea level. The Colorado River Basin is composed of a complex of rugged mountains, high plateaus, deep canyons, deserts and plains. Principal physical characteristics of this region are its variety of land forms, topography and geology.

The Colorado River Compact of 1922 established a division point on the Colorado River at Lee Ferry, Arizona, to separate the Colorado River Basin into an upper basin and a lower basin for legal, political, institutional and hydrologic purposes. Lee Ferry is located about 1 mile below the confluence

R. Freeman

of the Paria River and approximately 17 miles downstream from Glen Canyon Dam. The Upper Basin encompasses about 45 percent of the drainage area of the basin and the Lower the remaining 55 percent.

In addition to the Colorado River Basin, the project's investigations covered the area of southern California receiving Colorado River water. This area of about 15,400 square miles includes the Imperial and Coachella Valleys which surround the Salton Sea as well as the metropolitan areas of Los Angeles and San Diego.

Climate extremes in the basin range from hot and arid in the desert areas to cold and humid in the mountain ranges. Precipitation is largely controlled by elevation and the orographic effects of the mountain ranges. At low elevations, or in the rain shadow of coastal mountain ranges, desert areas may receive as little as 6 inches of precipitation annually, while high mountain areas may receive more than 60 inches.

Again, for those of you who wish to follow, I am now reading from page 11 of the Summary Report document.

Basin temperatures range from temperate, affording only a 90-day growing season in the mountain meadows of Colorado and Wyoming, to semi-tropical with year-round cropping in Yuma and Phoenix. On a given day, both the low and high temperature extremes for the Continental United States frequently occur at points within the basin.

In the southern California water service area, the climate of the area surrounding the Salton Sea is hot and arid, while the climate of the coastal metropolitan areas is moderated by proximity to the Pacific Ocean.

The Colorado River Basin is sparsely populated. In 1965 the estimated population was nearly two and a quarter million. The average density was about 9 persons per square mile as compared with the national average of 64. Eighty-five percent of the population lived in the Lower Basin. About 70 percent of the Lower Basin population resided in metropolitan areas, those at Las Vegas, Nevada, Phoenix and Tucson in Arizona.

The population of the Colorado River Basin will be--it is estimated that the population of the Colorado River Basin will triple by 2010.

The southern California water service area contained an estimated 11 million people in 1965. Most of the population was concentrated in the highly urbanized Los Angeles-San Diego metropolitan complex.

The economy of the basin is based on manufacturing, irrigated agriculture, mining, forestry, oil and gas production, livestock and tourism. The present economy of the Upper Basin is still largely resource oriented.

In the last two decades, however, the economy of the lower basin has experienced a significant transition from an agricultural and mining base to a manufacturing and service base. Growth in the manufacturing sectors has been one of the major factors in the overall economic growth of the Lower Basin. Important manufacturing categories are electrical equipment, aircraft manufacturing and parts, primary metals industries, food and kindred products, printing and publishing, and chemicals. However, agriculture continues to play an important role admidst the fast-growing industrial and commercial activity of the lower basin.

Turning our attention to water resources, an average of about 200 million acre-feet of water a year is provided by precipitation within the Colorado River Basin. All but about 18 million acre-feet of this is returned to the atmosphere by evapotranspiration. Most of the stream flows originate in the high forest areas where heavy snow packs accumulate and evapotranspiration is low. A small amount of runoff originates at lower altitudes, primarily from infrequent storms. Approximately two-thirds of the runoff is produced from about 6 percent of the Upper Basin area.

Stream flows fluctuate widely from year to year and season to season because of variations in precipitation and numerous reservoirs have been constructed to make water available for local needs, for exports, and for downstream obligations. The usable capacity of basin reservoirs is about 62 million acre-feet.

In addition to State laws which provide for intrastate control of water, use of water in the Colorado River system is governed principally by four documents: the Colorado River Compact signed in 1922, the Mexican Water Treaty signed in 1944, the Upper Colorado River Basin Compact signed in 1948, and the Supreme Court decree of 1964 in the case of Arizona versus California.

Among other provisions, the Colorado River Compact apportions to each of the Upper and Lower Basins in perpetuity the exclusive beneficial comsumptive use of 7.5 million acre-feet of water from the Colorado River system each year. It further establishes the obligation of the upper division not to cause the flow of the river at Lees Ferry to be depleted below an aggregate of 75 million acre-feet for the period of any 10 consecutive years.

The Mexican Water Treaty defines the rights of Mexico to use of water from the Colorado River system. It guarantees the delivery of 1.5 million acre-feet of Colorado River water annually from the United States to Mexico.

The Upper Colorado River Basin Compact guarantees Arizona 50,000 acre-feet of water and apportions the remaining 7.5 million acre-feet among the Upper Basin States on a percentage basis.

In 1965 about 0.5 million acre-feet of water was exported out of the Upper Basin for use in other parts of the Upper Basin States. Gross diversions from the lower Colorado River for use in the southern California service area and the lower Colorado River area in California totaled about 5.35 million acre-feet in 1965.

The major use of water within the basin is for agricultural, municipal and industrial purposes. At present, over 90 percent of the total basin withdrawal from ground and surface water sources serves irrigated agriculture within the basin. The remaining portion is used principally for municipal and industrial use. Approximately three-fourths or 7 million acre-feet of the water consumptively used in the basin each year is depleted by agricultural uses. Minor quantities of water are consumed by hydroelectric and thermal power production, recreation, fish and wildlife, and other such uses. In the urban areas of the basin, municipal and industrial uses are increasing significantly due to the rapid rate of population growth.

One of the largest causes of stream flow depletion in the basin is surface evaporation from storage reservoirs. Over 2.0 million acre-feet of water are estimated to evaporate annually from the lakes and reservoirs in the basin. Most of this evaporation is from major storage reservoirs on the main stem of the Colorado River.

With this brief discussion of the setting and conditions of the river, at this point I would like to turn to Mr. Blackman for a presentation of the project studies of salinity problems within the basin.

WILLIAM C. BLACKMAN

REGION VIII

U. S. ENVIRONMENTAL PROTECTION AGENCY

DENVER, COLORADO

MR. BLACKMAN: Mr. Chairman, conferees. I am William C. Blackman. During the period of the field engineering studies which I am about to describe I was Chief, Pollution Source Evaluation Section, Colorado River Basin Water Quality Control Project.

There are two basic causes of salinity increases in streams. These are the salt loading effect and the salt concentrating effect. The salt loading effect is the addition of minerals to streams by dissolution of mineral matter and addition of the solutes to streams. The salt concentrating effects are those such as evapotranspiration which abstract water from the stream system, leaving the salt burden in the watershed. A more detailed explanation of these effects is provided in Chapter II of Appendix A.

As part of its overall study of the mineral quality problem, the Colorado project carried out a thorough review and statistical analysis of past water quality data and made detailed field investigations of present conditions. The statistical studies were designed to identify significant changes in mineral quality with respect to time and distance, to define the relationships of natural and manmade hydrogeological factors, and to assist in the selection of points or reaches of stream where additional sampling was needed.

In order to analyze the changes in quality with respect to time, we selected the total dissolved solids or TDS data as the input statistic. TDS is a broad analytical procedure which is generally indicative of mineral quality. Moreover, TDS was the only parameter other than pH or specific conductance which has been reported continuously throughout the period of record at each sampling station.

It is necessary that input data for use in statistical analyses be suitable for the particular analysis being used. We initially attempted to apply the standard analytical technique known as analysis of variance using yearly average TDS concentrations. In order for the analysis of variance to be valid, it is necessary--can we dim the lights?--it is necessary that the data occur in a normal distribution. In other words, 95 percent of all observed values should fall within two standard deviations of the mean.

...Slides...

This figure illustrates the normal distribution wherein frequency of observation is plotted vertically and the measured values are plotted horizontally, giving the familiar bell-shaped curve of a normal distribution.

Our initial examination of the data for unregulated streams of the Colorado River Basin revealed a bi-modal distribution of TDS concentrations. Those of you who have Appendix A will recognize this slide as Figure 1 in the Appendix. Bi-modal distributions such as those illustrated indicate that two different populations were sampled. Most of the low TDS concentrations are associated with the high spring runoff flows, whereas TDS values associated with the second peak on the plots are for the low stream flow months.

We discovered that by separating the data for the runoff months and the base flow months the frequency of occurrences of TDS concentrations at most stations were normally distributed or sufficiently so that analysis of variance could be used.

In Figure 4 in Appendix A you see the distribution of monthly mean TDS concentrations for base flow months for the Eagle River near Gypsum, Colorado.

During runoff months, as shown in Figure 7 of the appendix, the distribution also approximates a normal distribution curve except that the curve is skewed slightly toward the lower values.

Downstream of the major impoundments, as might be expected, the frequencies of occurrences of TDS concentrations are distributed normally due to the mixing effect of the major reservoirs. This is the distribution curve for the Colorado River at Parker Dam.

The analysis of variance compares the variance in means for periods of time in which apparent changes took place. These periods were identified by the use of mass curve techniques such as illustrated here. This is Figure 9 in your appendix. The break which you see occurred here in water year

1954 defined the two periods which were selected for testing at this particular station. Test of this apparent increase by analysis of variance showed the change to be significant and the cause for the increase was found to be reduced stream flow.

Now, the foregoing is an explanation of the statistical methods whereby we reached conclusions concerning changes in salinity with respect to time in the Colorado River and these are the conclusions:

During base flow months, that is August through March, four stations located above Hoover Dam exhibited increases in TDS concentrations, four show decreases, and two experienced both increases and decreases. TDS concentrations increased significantly at five stations above Hoover Dam during runoff months. There were no cases of statistically significant decreases in salinity during the runoff months at these stations. It is significant that only increases in TDS occurred during the runoff months.

It is during these runoff months that most of the yield or water supply of the Colorado Basin flows into the reservoirs for use by irrigators, industries, and municipalities of the basin and its adjacent water service areas.

The analyses of changes in mineral quality with respect to distance were carried out in essentially the same

W. C. Blackman

manner and the results were entirely predictable. Proceeding in the downstream direction, there were statistically significant increases in TDS concentrations between each pair of upstream and downstream stations. For example, on the Colorado River during base flow months, yearly mean TDS concentrations increased from 94 mg/l at Hot Sulpher Springs to 402 mg/l at Glenwood Springs to 732 mg/l at Cameo, and so on downstream. During runoff months at the same time TDS concentrations increased from 77 mg/l at Hot Sulpher Springs to 208 mg/l at Glenwood Springs to 265 mg/l at Cameo, and again so on downstream.

I will now describe for you briefly and summarize the field surveys which were carried out to define stream reaches in which major changes in salinity and mineral composition occur and to identify those sources which might be amenable to control.

This map, which is Figure 14 in Appendix A, shows the network of sampling stations operated by project personnel and the U. S. Geological Survey at key locations on principal streams in the upper basin. Those stations where just a half circle is shown are the long-term USGS stations that were incorporated into this work. These stations were selected to provide measurement of salt loads entering and leaving significant watersheds and to define the magnitude of changes in mineral composition within critical reaches of streams.

Here are the sampling locations in the Lower Basin. Once again we incorporated the USGS stations and also two stations operated by the Metropolitan Water District of Southern California.

We subdivided the basin into a number of hydrologic units, which were usually watersheds, which we refer to in the report as study areas. Within each study area we measured the salt yields attributable to discrete or point sources such as springs, seeps, abandoned oil test wells, municipal and industrial discharges, cooling water, surface return flows from irrigated areas, producing oil fields, and coal and metal mining operations. With this information we then developed water and salt load budgets for each area.

A budget in water quality terms is an accounting of the amount of salt and water entering, originating in, and leaving an area. From these budgets the contributions from diffuse sources such as leaching and seepage associated with irrigation and direct overland runoff to streams were calculated. This technique is described in a general way in Appendix A and more fully by Vaughn Irons and his associates in U. S. Geological Survey Professional Papers 441 and 442.

I have singled out a typical study area to illustrate the type of information which was developed for each study area. This example, which is referred to in the report as Study Area 23, includes the entire drainage area of the Dolores and San Miguel Rivers as seen in this slide. This is Figure 36 in Appendix A. The study area covers 45,000 square miles in Montezuma, Dolores, San Miguel, Montrose and Mesa Counties in Colorado and Grand and San Juan Counties in Utah. As you can see in this illustration, TDS increased from 137 mg/l in the headwaters of the Dolores to 966 mg/l below Bedrock. This increase is primarily attributable to salt accretions from the Paradox formation.

On the San Miguel River, TDS concentrations increased from 130 mg/l in the headwaters to 462 mg/l at the mouth.

The salt budget developed for this area--next slide, please--the salt budget developed for this area is as shown in this slide. As you can see, irrigation contributed 46 tons/day or 2.8 percent of the total load, industrial effluent and seepage from industrial ponds contributed 119 tons/day or 7.2 percent of the total load, springs and salt seeps contributed 695 tons/day or 41.8 percent of the total load, mine drainage contributed 20 tons/day or 1.2 percent, and runoff contributed 780 tons/day or 47 percent.

Mr. Chairman, at this point I wish to enter into the record a correction on page 119 of Appendix A. The percentages which I have just enumerated should be substituted for those which are tabulated on page 119 of the report.

MR. STEIN: That will be done.

MR. BLACKMAN: The water and salt budget method utilized in these studies is well suited to headwaters areas where stream flow and quality are sensitive to small inputs of water and salt. The method is less suitable for downstream reaches where errors in flow measurement or laboratories analyses can mask or distort the calculated response to salt inputs. Owing to the very large diversions and highly developed systems of irrigation drains, the Lower Colorado River Basin studies were treated in terms of the effects of salt load inputs and stream diversions. The data developed regarding each source was then evaluated to determine possibilities and benefits to be derived from control. Mr. Vincent will summarize the control aspects of this work following this presentation.

During the period June 1965 through May 1966 the mean flow from the Upper Colorado Basin was 19,263 CFS. The salt load discharged into Lake Powell during the same period averaged 26,160 tons/day. The relative magnitudes of salt loads contributed by various types of sources in the Colorado Basin are summarized graphically in this slide, which is Figure 45 in the appendix. As you can see, in the Upper Basin 52 percent of the salt load was contributed by runoff, 37 percent by irrigated agriculture, 9 percent by natural point sources in wells, and 2 percent by municipal and industrial sources. In the Lower Colorado River Basin 72 percent of the entire salt load was contributed by the sources we have just talked about in the Upper Colorado Basin. Natural point sources contributed 15 percent, runoff contributed 4 percent, irrigated agriculture 9 percent,and municipal and industrial sources less than 1 percent.

This next slide, which is Figure 47 in Appendix A, illustrates graphically the relative salt loads from irrigated areas throughout the Colorado River Basin. The area contributing the largest amount of salt load--the irrigated area contributing the largest amount of salt load is the Gunnison River Basin in the Upper Basin, which contributed 29 percent. This is mostly from irrigated areas in the Delta-Montrose area, the Grand Valley area, which contributed 18 percent. These irrigated areas are mainly in the Grand Junction area. Other areas in the upper main stem contributed 5 pereent.

In the Green River subbasin the irrigated areas in the Duchesne River, that is in eastern Utah, contributed 13 percent; those in the Price River Basin contributed 5 percent;

the Lyman area in southwestern Wyoming contributed 4 percent; other irrigated areas in the Green subbasin contributed 10 percent.

Of the salt loads contributed by irrigated areas, those in the San Juan River subbasin contributed 5 percent and in the lower main stem subbasin 11 percent.

Now, this next slide, which is Figure 48, shows the actual salt yields in tons/acre per year from various irrigated areas in the basin. These range from almost 0 for the irrigated areas of the Green River above the New Fork River to approximately 8.5 tons per acre per year for the irrigated areas on the Price River. I think it is noteworthy that the Colorado River Indian reservation yield was approximately 0.5 ton per acre per year while the Palo Verde irrigation district just across the river, situated on the same alluvial structure and irrigating the same type of soil, yielded more than 2.0 tons per acre per year. This difference is attributable to the fact that the irrigated areas on the Indian reservation were nearly all tile drained and well leached, while drains in the Palo Verde district were being deepened and additional leaching was taking place during the period of the investigation. These kinds of considerations bear heavily upon salinity control feasibility decisions.

W. C. Blackman

This figure, which is Figure 49 in the appendix, compares the relative magnitude of some of the major springs and point sources of salt in the Colorado Basin. As you can see, the largest single point source in the whole basin is Blue Spring, which is situated at the mouth of the Little Colorado in the Lower Basin. The load contributed there is approximately 1,500 tons/day, and to get some perspective of this, if you were to evaporate the water from this discharge you would have a train of about 30 hopper cars full of dry salt per day issuing from this spring. The Paradox Valley formation contributes 15 percent--let's continue the Lower Basin. In the Lower Basin La Verkin Spring contributes 6 percent and other point sources 5 percent. In the Upper Basin the largest natural point source is Glenwood Spring contributing 23 percent, the Paradox Valley contributing 15 percent, Dotsero Spring 10 percent, and other sources 7 percent.

In the San Juan subbasin the Mancos shale of the La Plata and McElmo Creeks cause the waters of the San Juan to become predominantly calcium sodium sulfate type. In the Green River subbasin irrigation return flows and runoff from Eocene lake beds causes similar changes in the predominant ions. In the upper main stem of the Colorado, runoff and irrigation return flows in the Uncompahgre and the highly saline formations of the Dolores River cause the upper main stem to become predominantly calcium sodium sulfate type waters. Increasing concentrations of these constitutents cause higher treatment costs for use by a wide range of industries and increased leaching requirement for irrigated crops, and,in fact,damage to some crops. In the lower main stem this predominance continues down to the intensely irrigated areas of the Colorado River Indian reservation, the Palo Verde irrigation district and the Gila project where the irrigation returns cause the river to become predominantly sodium chloride type. In addition to the effects described earlier, waters high in sodium and chloride are directly toxic to sensitive plants. Now, there is a much more detailed description of these effects in Appendix B of your report.

Ionic diagrams are provided in Figures 50 through 53 of Appendix A,which also will give you a rundown on the changes in mineral composition which take place throughout the basin.

May we have the next slide, please?

This summary brings up to date the salinity data for key stations in the basin. In the upstream stations, Cameo and Green River, you can see that between 1960 and 1970 there were the usual fluctuations in total dissolved solids concentration, most of these attributable to differences in yield in that particular--that is, runoff in that particular basin. Lee's Ferry and Grand Canyon, Arizona, some increase can be seen between 1960 and 1970. It is important to note that the large value 1,030 mg/l at Grand Canyon in 1963 is associated with the closure of Glen Canyon Dam and should not be considered a normal value.

Proceeding on downstream, we really don't need a statistical analysis to see that at Parker Dam and at Imperial Dam there have been substantial increases between 1960 and 1970, at Parker Dam from 631 mg/l to 764 mg/l and at Imperial Dam from 777 mg/l to 927 mg/l.

We do not show earlier data for the northerly international boundary there because salinity is greatly affected by the Weldon-Mohawk bypass channel which was constructed about the middle of the period.

Mr. Chairman, Mr. Jim Russell will now present the physical and economic impacts of these salt sources which I have described.

JAMES D. RUSSELL
REGION IX
U. S. ENVIRONMENTAL PROTECTION AGENCY
SAN FRANCISCO, CALIFORNIA

MR. RUSSELL: Mr. Chairman, conferees.

My name is James D. Russell and during the period of investigations of the salinity problem of the Colorado River Basin I was Chief of the Planning Branch of the Colorado River Basin Office.

Long-term average salinity levels have progressively increased in the Colorado River system as the basin's water resources have been developed and consumptive use of water for various purposes has increased. This trend is expected to continue with future water resource development and to bring about serious water quality implications. As the economic impact of salinity is closely related to the rate at which salinity levels rise in the future, an evaluation was made of present and future salinity concentrations in the basin to provide the basis for the economic evaluation I will discuss in the next few minutes.

Historical salinity and stream flow data for the 1942 through 1961 period of hydrologic record were used as the basis for estimating average salinity concentrations under various conditions of water development and use. This historical data was modified to reflect the effects that water uses existing in 1960 would have had on average salinity levels if these uses had existed during the full 20-year period. Average salinity concentrations obtained from this modified data were designated as 1960 base conditions.

Predicted future conditions of water use, based on Federal, State and local development plans available in 1967, were utilized to develop detailed projections of 1980 and 2010 salinity levels. These projections were based on the assumptions that water resource development would proceed as planned in 1967 and that the 1942 through 1961 hydrologic record would be repeated. These projections are for long-term average salinity concentrations. Actual concentrations can be expected to fluctuate about these averages as a result of seasonal changes in stream flow and other hydrological facters.

Figure 5, which is found in Appendix B, from which most of my presentation will be taken, displays these projected concentrations at nine stations in the basin. It is particularly important, I think, to note the concentrations at Hoover Dam and Imperial Dam, because for our analysis these became rather critical points in the system.

1960 base concentrations were 697 mg/l at Hoover Dam and 759 mg/l at Imperial Dam.

On the basis of the assumptions I just described, these concentrations were calculated to rise to 876 mg/l at Hoover Dam in 1980 and 1,056 mg/l at Imperial Dam in 1980.

For the year 2010, which was the last target year of our analysis, the concentrations were calculated to be 990 mg/l at Hoover Dam and 1,223 mg/l at Imperial Dam.

It is important to recognize that salinity concentrations projected for the Colorado River depend heavily upon many factors, among which are assumptions of the base period of record and the assumed pattern of future development. For example, the Colorado River Board of California estimated a concentration of 1,070 mg/l at Imperial Dam for 1980, which compares quite favorably to our estimate of 1,056 mg/l at that location.

On the other hand, the Water Resources Council, using projections of economic development prepared by the Office of Business Economics and the Economic Research Service of the Department of Agriculture, predicted a concentration of 1,260 mg/l at Imperial Dam in 1980.

To provide the degree of refinement necessary to allow evaluation of the small incremental changes in salinity levels produced by a given water resource development, salinity concentrations were computed to the nearest mg/l in making the projections shown in Figure 5. However, it is not intended that a high degree of accuracy be implied by these numbers.

It is significant that in the past, salt loading was the dominant factor affecting salinity concentrations, contributing about three-fourths of average salinity concentrations at Hoover Dam under 1960 conditions. In contrast, future increases in salinity levels will result primarily from flow depletions caused by out-of-basin exports, reservoir evaporation, and consumptive use of water for municipal, industrial, and agricultural purposes.

Projections for Hoover Dam indicate a relatively constant average salt load over the next 40 years, but a substantial drop in water flow. Over 80 percent of the future increase in salinity concentrations at Hoover Dam will be the result of increases in flow depletions. Over three-fourths of the projected salinity increase between 1960 and the year 2010 will be the result of increases in reservoir evaporation brought about by the filling of major storage reservoirs completed since 1960 and of increases in consumptive use brought about by the expansion of irrigated agriculture.

Water uses exhibit an increasing sensitivity to rising salinity concentrations. As concentrations of salinity rise, water use is progressively impaired until at some critical level, defined as a threshold level, utilization of the supply becomes restricted. In the Colorado River Basin, future salinity concentrations will be below threshold levels for instream uses such as recreation, hydroelectric power generation, and propagation of aquatic life. Only marginal impairment of these uses is anticipated.

In the lower Colorado River, however, present salinity concentrations are above threshold levels for municipal, industrial and agricultural uses. Some impairment of these uses is now occurring and future increases in salinity will increase this adverse impact.

The project investigated these progressive impairments of water uses and developed methods to quantify the resulting economic impact on both water users and on the regional economy. It should be emphasized that the methodology employed by the project staff was intentionally conservative. All costs developed by this report to describe the impact of salinity must be considered minimal values.

Initial investigations conducted on the potential impact of future salinity levels revealed that only small effects on water uses could be anticipated in the Upper Basin. Subsequent investigations, therefore, were limited to three main study areas: the lower main stem and Gila areas in the Lower Basin and the southern California area encompassing the southern California water service area. The boundaries of these study areas follow political rather than hydrological boundaries and are shown in Figure 3 of Appendix B.

The lower main stem study area includes Clark and Lincoln Counties in Nevada, Washington County in Utah, and Mohave, Coconino and Yuma Counties in Arizona. The southern California water service area includes Santa Barbara, Ventura, Los Angeles, San Bernardino,Orange, Riverside, San Diego, and Imperial Counties in California.

The Gila study area includes Cochise, Gila, Graham, Greenlee, Maricopa, Pima, Pinal, Santa Cruz and Yavapai Counties in Arizona and Catron County in New Mexico.

Irrigated agriculture accounts for most of the water use in these areas, amounting to over 70 percent of the river water used in the lower main stem and southern California areas. For the Gila study area there will be very little impact until 1980, when water deliveries to the central Arizona project were assumed to begin.

May we have the lights back on?

Initial evaluations of possible salinity effects on basin water uses indicated that adverse physical effects would essentially be limited to municipal, industrial, and agricultural uses.

Domestic uses comprise the major utilization of municipal water supplies. Total hardness, a parameter closely related to salinity, is of primary interest in assessing water quality effects on these uses. Increases in the concentration of hardness lead to added soap and detergent consumption, corrosion and scaling of metal water pipes and water heaters, accelerated fabric wear, added water softening costs, and in extreme cases abandonment of a supply, which may force a community or a group of citizens, at any rate, to go to a bottled water supply. By most hardness measures, raw water supplies derived from the Colorado River at or below Lake Mead would be classified as very hard.

Boiler feed and cooling water comprise a major portion of water used by industry in the basin. Mineral quality of boiler feed water is an important factor in the rate of scale formation on heating surfaces, degree of corrosion in the system,and quality of produced steam.In cooling water systems, resistance to slime formation and corrosion are affected by mineral quality. The required mineral quality levels are maintained in boiler and cooling systems by periodically adding an amount of relatively good quality water, termed makeup water, and discharging from the system an equal volume of the poorer quality water, termed blowdown.

Salinity effects on agricultural uses are manifested primarily by limitations on the types of crops that may be irrigated with a given water supply and by reductions of crop yields as salinity levels increase. Other conditions being equal, as salinity levels increase in applied irrigation water, salinity levels in the root zone of the soil also increase.

Because different crops have different tolerances to salts in the root zone, limits are placed on the types of crops that may be grown. When salinity levels in the soil increase above the threshold levels of a crop, progressive impairment of the crop yield results. Irrigation water which has a high percentage of sodium ions may also affect soil structure and cause adverse effects on crop production. Truck crops such as carrots, onions, melons, lettuce, sweet corn, and tomatoes, as well as citrus crops such as oranges, lemons, and grapefruit, have already been detrimentally affected by the application of Colorado River water.

The primary means of combatting detrimental salinity concentrations in the soil are to switch to salt-tolerant crops such as sorghum, barley or oats, or to apply more irrigation water and leach out excess salts from the soil.

J. D. Russell

The physical impacts which I have just described of salinity upon consumptive uses of water were translated into economic values by evaluating how each user might alleviate the effects of salinity increases. Municipalities could: 1) do nothing and the residents would consume more soap and detergents or purchase home softening units; 2) they could build a central water softening plant; or 3) they could develop a new less mineralized water supply.

Industrial users could combine more extensive treatment of their water supply with the purchase of additional make-up water based upon the economics of prevailing conditions.

The alternatives available to irrigation water users are governed by the availability of additional water. 1) The irrigator could, if he does nothing, suffer economic loss from reduced crop yields. 2) If additional water is available, root zone salinity may be reduced by increasing leaching water application. The irrigator in this case would incur increased costs for the purchase of water, for additional labor for water application, and for increased application of fertilizer to replace the fertilizer leached out. Or 3) if no additional water is available, the irrigator can increase the leaching of salts from the soil by applying the same amount of water to a lesser acreage. This, of course, results in an economic loss, since fewer crops can be grown. 4) The last alternative is to plant salt-tolerant crops, such as sorghum, in which case an economic loss will usually occur, since the salt-tolerant crops primarily produce a lower economic return.

The cost of applying each of the alternative remedial actions was determined and the least costly alternative selected for subsequent analysis. The yield-decrement method, which measures reductions in crop yield resulting from salinity increases, was selected to evaluate the direct economic impact on irrigated agriculture. For industrial uses, an estimate of required makeup water associated with salinity increases was selected to calculate the direct economic cost. Direct municipal costs were estimated by calculating the required additional soap and detergents needed.

In addition to the direct economic costs incurred by the users of Colorado River water, there are indirect effects on the regional economy because of the interdependence of numerous economic activities. These effects, termed indirect costs, can be determined if the interdependency of economic activities are known.

The project's economic base study investigated the interdependence of various categories of economic activity or sectors. These were quantified for 1960 conditions and were projected for the target years 1980 and 2010. A digital computer program was developed to follow changes affecting any given industry through a chain of transactions in order to identify secondary or indirect economic costs of salinity.

The sum of direct user costs and indirect costs suffered by the regional economy are termed total salinity detriments. The detailed economic analysis used to derive total salinity detriments is discussed in detail in Appendix B. For the purposes of this presentation, we will discuss results of that analysis as applied to expected salinity levels at Hoover Dam.

Hoover Dam is a key point on the Colorado River system. Water quality at most points of use in the Lower Basin and southern California water service area may be directly related to salinity levels at Hoover Dam. Modifications of salt loads contributed by sources located upstream from Hoover Dam also directly affect salinity levels at this location. Salinity concentrations at Hoover Dam were, therefore, utilized as a water quality index to which all economic evaluations were keyed.

The table now displayed shows that under 1960 conditions the annual economic impact of salinity was estimated to total $9.5 million. Although not shown on this table, we have estimated that present salinity detriments, those occurring in 1970, have increased to an annual total of \$15.5 million. If water resources development proceeds as proposed and no salinity controls are implemented, it is estimated that average annual economic detriments would increase to \$27.7 million annually in 1980 and \$50.5 million in the year 2010.

May we have the lights, please.

It should be noted that the majority of salinity detriments or nearly 82 percent will result from water use for irrigated agriculture. This fact may be attributed to the heavy utilization of Colorado River water for irrigation along the lower Colorado River and in southern California.

Also important is that we found that over three-fourths of the salinity detriments will be incurred in the southern California water service area. These costs will result primarily from agricultural use in the Imperial and Coachella Valleys and municipal and industrial uses in the coastal metropolitan areas.

Salinity detriments in the Gila study area will be minor and will not occur until after 1980 when water deliveries to the central Arizona project were assumed to begin.

It must be remembered that the methodology employed by the project staff was intentionally conservative. All costs developed by this report to describe the impact of salinity must be considered minimal values. Comments received from California bear out this fact. In his letter of June 4, 1971, Mr. Jerome Gilbert concluded that, and I quote:

> We believe that the penalty costs developed in the report show the severity of the problem but must be considered minimum values. Our reasons for this conclusion are as follows:
>
> > In the report, the cost impact on urban uses is related almost entirely to the cost of softening hard water in central system softening plants. A number of recent technical articles and reports have stated that softening costs are only one aspect of the total cost impact in urban areas. A major cost impact is the deleterious effect of water high in salinity and in hardness on the water purveyor facilities, on distribution systems, on the water pipes and appliances within and on user premises, and on horticultural effects in residential

> and urban areas. The cost impact from these causes has been variously estimated by investigators to be no less than $5 per acre foot of water used per 100 ppm increase in salinity. In addition to these costs discussed in various technical papers and reports, there are the costs resulting from increased use of bottled water, costs of maintaining private swimming pools, and the generally adverse effects of poor taste of high salinity water supplies.

The second point which Mr. Gilbert made was that:

> The agricultural impacts of high salinity water are also understated in that they are predicated upon the yield-decrement method of analyzing cost impacts. Irrigators in California have not been accepting lower yields in accordance with the yield-decrement method, but have been spending millions of dollars attempting to maintain yields through installation of subterranean tile drains, increasing water

applications, and changing to expensive methods of irrigation. End quote.

That concludes this portion of the EPA presentation. At this point I would like to introduce--

MR. STEIN: Just a moment. We are going to recess for lunch.

Because of commitments that some people have, we will reconvene promptly at 1:30.

(Whereupon, at 12:10 o'clock a noon recess was taken.)

AFTERNOON SESSION

TUESDAY, FEBRUARY 15, 1972

1:30 o'clock

MR. STEIN: Let's reconvene.

Mr. Dickstein.

MR. DICKSTEIN: Mr. Vincent, please.

JAMES VINCENT

REGION VIII

U. S. ENVIRONMENTAL PROTECTION AGENCY

DENVER, COLORADO

MR. VINCENT: Mr. Chairman, and conferees.

My name is James Vincent. During the salinity studies conducted by the Colorado River Basin Project which we are discussing here today I was Senior Engineer in the Water Quality Management Unit.

A dilemma confronts the Colorado River Basin States. If no action is taken to manage present salinity levels, future economic development that results in further increases in salinity levels will in turn produce adverse economic effects on the basin economy. Implementation of controls to minimize salinity increases would require a major expenditure of funds. Regardless of the action taken by the States, a substantial economic effect will result.

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A number of alternative approaches to solution of this dilemma are available to the States. An awareness of the water quality and related economic effects associated with these alternative approaches is essential before a rational decision can be made regarding the course of action best suited to meeting State and Federal objectives for enhancement of water quality and wise utilization of the basin's resources.

In my presentation, I will discuss the various alternative approaches available, the technical possibilities for salinity control, control measures considered most practical, potential salinity control programs, and the economic impact of various levels of salinity control. Detailed discussions of the various salinity control and management aspects are contained in Appendix C, to which I will be referring throughout my presentation.

Three basic approaches, or a combination of these approaches, might be used to achieve a solution to the salinity problem: 1) we could do nothing; 2) limit development; or 3) implement salinity controls.

The first approach would achieve no management of salinity. Water resource development would be allowed to proceed with no constraints applied because of water quality degradation and with no implementation of salinity control

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works. This approach, in effect, ignores the problem and allows unrestrained economic development at the expense of an increased adverse economic impact resulting from rising salinity concentrations. Mr. Russell just before lunch discussed increases in future salinity levels and economic impact associated with this approach.

The second approach would limit economic or water resource development that is expected to produce an increase in salt loads or stream flow depletions. Such an approach would minimize future increases and economic impact of salinity and possibly might eliminate the need for salinity control facilities. It has the obvious disadvantage, however, of possibly stagnating growth of the regional economy.

The third approach, calling for construction of salinity control works, would allow water resource development to proceed. Salinity controls could be implemented to meet a number of possible objectives such as maintaining specific salinity levels or minimizing the economic impact of salinity increases.

A wide range of technical possibilities for minimizing and controlling salinity exists. These may be divided into two categories: water-phase and salt-phase control measures. Water-phase measures seek to reduce salinity concentrations by augmenting the water supply, while salt-phase measures seek to reduce salt input into the river system.

In the course of the salinity investigations carried out by EPA and its predecessor agencies, the potential feasibility of applying each technical possibility to the Colorado River was evaluated and the most practical approaches selected for further study. The various technical possibilities which may be applicable to the Colorado River Basin are listed in Table I on page 13 of Appendix C.

Various factors, such as economic feasibility and legal and institutional constraints, limit the present application of most control measures.

Water conservation measures, which are listed under Item 1A of the table, are limited in their practicality as means of increasing the water supply available for dilution of salinity concentrations. The most practical means of increasing the water supply are listed under Item 1B of the table. These include importing water from other basins, importing demineralized sea water, and the use of weather modification techniques to increase precipitation and runoff.

As you can see from Table 1, a large number of technical possibilities exist for reduction of salt loads contributed by natural and manmade sources. Only a few of these methods are considered practical. These include impoundment and evaporation of point source discharges, diversion of runoff in streams around areas of high salt pickup, improvement of irrigation and drainage practices, improvement of irrigation conveyance facilities, desalination of saline discharges from natural and man-made sources, and desalination of water supplies at point of use.

Eight potential salinity control programs incorporating the most practical control measures were formulated as a means of evaluating the magnitude, scope and economic feasibility of a potential basinwide control program. These alternatives included three salt load reduction programs, four flow augmentation programs, and one program to demineralize water supplies at the point of use. A comparison of the costs and effects of these alternatives is presented in Table 3 on page 84 of Appendix C.

The three salt load reduction programs utilize control measures such as desalination or impoundment and evaporation of mineral spring discharges, irrigation return flows and saline tributary flows, diversion of streams, and improvement of irrigation practices and facilities. These programs would achieve estimated salt load reductions of up to 3 million tons annually and would reduce average annual salinity concentrations at Hoover Dam by about 200 to 300 mg/l.

The four flow augmentation programs evaluated were based on three potential sources of water: increased precipitation through weather modification, interbasin transfer of water, and importation of demineralized sea water. The volume of flow augmentation provided by these programs would range from 1.7 to 5.9 million acre-feet annually. Resulting reductions in annual salinity concentrations at Hoover Dam would range from 100 to 300 mg/l.

The last alternative program evaluated would utilize desalination of the water supplies diverted to southern California as a means of minimizing the adverse impact of salinity on the southern California water surface area.

Estimated average annual program costs ranged from $3 million to $177 million. The present worth of the total program costs for each alternative from 1975 to 2010 ranged from $30 million to $1,570 million.

The eight alternative programs evaluated were not directly comparable due to differences in the level of salinity control achieved, the multi-purpose aspects of some programs versus the singular salinity control natures of others, and the time required for implementation. Based on evaluation of a number of factors, including total program costs, practicality, the implementation time period, salinity control benefits, and other benefits such as increased water supply, the phased implementation of a salt load reduction program was selected as the least cost alternative for achieving basinwide management and control of salinity. Should the practicality of flow augmentation by weather modification be demonstrated by current pilot studies, however, the combination of such flow augmentation with a salt load reduction program would be a more optimal approach.

...Slides...

The salt load reduction program selected was designed to reduce the salt load contributed by five large natural sources and 12 irrigated areas totaling 600,000 acres. Locations of potential projects are shown in this slide, which is Figure 3 in Appendix C. Together the five natural sources contribute about 14 percent of the basin salt load. All of the irrigated areas selected exhibited high salt pickup by return flows of about 3 to 6 tons per acre per year. Although this acreage comprises only about 20 percent of the basin's irrigated area, the 12 areas contribute about 70 percent of the salt load from irrigation sources above Hoover Dam.

Here in the Las Vegas area a potential project was designed to eliminate the salt load carried by Las Vegas wash.

Waste disposal practices proposed for municipal and industrial waste sources in Las Vegas Valley by the Environmental Protection Agency in a recent water quality standards enforcement action when implemented will essentially eliminate the Las Vegas wash salt concentration. This will result in a decrease of about 10 mg/l in average annual salinity concentrations at Hoover Dam. Proposed practices include impoundment and evaporation of industrial wastes and export of municipal wastes to a closed basin. Potential projects at La Verkin, Blue and Glenwood Springs would reduce the salt load contributed by these large mineral springs. Impoundment and evaporation of spring flow would be used for control of La Verkin Springs while most of the flow from other springs would be demineralized in desalination plants. In Paradox Valley the Dolores River would be diverted around an area of very high salt pickup.

For the 12 irrigated areas, control measures would be implemented to reduce the volume of irrigation return flows which pick up large salt loads from saline soils and groundwater systems. Improvement of on-farm irrigation efficiencies by modification of irrigation practices, improvement of irrigation facilities, reduction of excessive water applications, implementation of areawide irrigation scheduling services, and information programs for irrigators would have the largest impact on reducing return flows and accompanying salt loads. Improvement of water conveyance systems by lining canals and laterals and installation of more automatic controls and measuring devices would also substantially reduce return flows.

If salinity concentrations are reduced by the implementation of control measures, certain costs known as salinity management costs will be incurred. The form and magnitude of these costs depend upon a number of factors including the control measures utilized and the degree of salinity control achieved.

Probable costs, salt load reductions, and changes in consumptive water use were estimated for each of the 17 projects in the selected salt load reduction program. The projects were then ranked on the basis of the unit cost of salt load reduction. Incremental reductions in average salinity levels at Hoover Dam were estimated using the predicted salt load and flow changes.

This slide shows the salinity management cost functions developed from the individual project data. This is Figure 11 in Appendix C. The functions relate cumulative management cost to cumulative salinity reductions. From the curves it is possible to evaluate the probable average annual cost of achieving a specffic level of salinity control. The slightly higher salinity reductions which can be achieved at 2010 relative to 1980 for the same cost result from the fact that the flow passing Hoover Dam in 2010 will be less than in 1980. A constant salt load reduction will thus produce a larger salinity reduction in the smaller flow.

It should be noted that salinity management costs increase rapidly for salinity reductions greater than 200 mg/l. In 2010 doubling the salinity reduction at Hoover Dam from 135 to 270 mg/l would result in a fourfold increase in management costs.

For a given salinity level there is an economic cost associated with water use, and this was discussed earlier when we defined it as salinity detriments, and a second economic cost associated with maintaining salinity concentrations at that level. These are salinity management costs there on the screen. The sum of these costs, defined as total salinity costs, is the economic indicator of most significance when considering the overall effects of any specific salinity management approach.

Total salinity cost functions can be developed by the addition of salinity detriment functions and salinity management cost functions.

Total salinity cost functions for each decade from 1970 to 2010 are shown in this slide. This is Figure 14 in

Appendix C. The right end of each curve corresponds to the predicted salinity level for that year if no controls are implemented. If controls are implemented, salinity levels would decrease, producing a displacement to the left along the cost curve. For low flow levels of salinity control, corresponding to short displacements leftward on the cost curves, total salinity costs are decreased over the no control situation. Total costs continue to decrease as higher levels of salinity control are implemented until some minimum cost is reached. Beyond this point, total salinity costs are increased by implementing additional salinity control measures. This particular characteristic of total cost functions results from the fact that the incremental costs of salinity reductions increase rapidly for high degrees of control, as was shown in the previous slide. It should be noted that total costs will increase substantially with time regardless of the degree of controls implemented. As a minimum, total salinity costs will double between 1970 and 2010.

As discussed earlier, the three basic approaches to solution of the salinity problem are to do nothing, limit development, or implement salinity controls. The total salinity cost functions provide the tools for evaluating the economic and water quality effects associated with these approaches.

Salinity controls could be implemented to meet a variety of management objectives which include both water quality and economic objectives. Three such objectives were selected for evaluation. These are:

1) Maintain salinity at a level which would minimize its total economic impact and achieve economic efficiency. We define this as a minimum cost objective.

2) Maintain salinity concentrations at some specified level. We call this the constant salinity objective. And

3) Maintain salinity at some low level for which the total economic impact would be equal to the economic impact that would be produced if no action were taken at all. And we call this the equal cost objective.

In addition to these three objectives, the no control and limited development alternatives were evaluated.

Predicted variations in total salinity cost versus time for the five alternatives evaluated are shown in the next slide, which is Figure 17 of Appendix C.

Total salinity costs would be minimized by the limited development alternative, which is the lowest curve on this graph. This approach might not be the most economical, however, when all effects on the regional economy are measured. Water resource developments are not constructed unless it has been demonstrated that such development will return economic benefits

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that exceed all costs of the development. A project which is economically feasible will thus produce a net improvement in the regional economy. If the project is not built, the net benefits of the project would be foregone, representing an economic cost. A determination of the net economic benefits foregone if the limited development approach were utilized was beyond the scope of the project's investigations. It is apparent, however, that if the annual net benefits foregone exceed $3 million in 1980 and $11 million in 2010, the total economic impact of limited development would exceed the impact of the minimum cost alternative.

If unrestricted water resource development is permitted, implementing salinity controls to achieve a minimum cost objective would minimize total salinity costs. This is the second curve from the bottom on the graph. The no-control and equal cost alternatives produce the identical highest average costs and most rapid increase with time of all the alternatives evaluated, and that is the top curve. Total costs associated with a constant salinity objective will fall somewhere between extremes established by the other alternatives with the exact cost dependent upon the target salinity level.

In our example we used a target level of 700 mg/l and for this case total costs approximate minimum costs until around 1990, then increase rapidly, eventually exceeding the no-control costs. That is the curve that extends up above the top curve at the end.

Selection of a higher target salinity concentration for the years 2000 and 2010 would reduce the total cost of this alternative. Maintaining a constant salinity of 800 mg/l after 1990 would produce costs comparable to the minimum cost alternative.

One important observation can be made. Regardless of the alternatives selected, the future economic impact of salinity will be great. Although implementing salinity controls will result in availability of better water quality for various uses and some of the economic impact will be shifted from salinity detriments to salinity management costs, the total economic impact of salinity will not be substantially reduced. As a minimum, average annual total salinity costs will double between 1970 and 2010. Selection of the limited development alternative would reduce total annual costs by only 40 percent below the no-control alternative in the year 2010.

This slide shows the variations with time of the predicted salinity levels associated with the five alternatives evaluated. With no controls implemented, average annual salinity concentrations at Hoover Dam are predicted to increase between 1960 and 2010 by about 42 percent or 293 mg/l. This is shown by the top curve. Selection of any of the other alternatives evaluated would substantially reduce future salinity levels or future salinity concentrations below the no-control levels. Except for the limited development alternative, these reductions would result in the maintenance of average salinity concentrations at or below present levels for more than 25 years. Resulting water quality, therefore, would be consistent with nondegradation provisions of the water quality standards adopted by the seven basin States. The limited development alternative would result in slight increases in average salinity concentrations.

The least cost alternative program, used as a basis for the evaluation of the economic feasibility of salinity control, was directed toward the objective of minimizing salinity concentrations on a basinwide basis. This objective was achieved by reducing the average salt load passing Hoover Dam, a control point for the quality of water delivered to most Lower Basin and all southern California water users. It is important to note that salinity concentrations increase substantially between Hoover Dam and Imperial Dam due to water use in the lower basin and exports of water to the metropolitan water district of southern California. Implementation of salinity control measures along the lower Colorado River could offset or minimize these salinity increases. Such measures have a higher unit cost for salinity reductions at Imperial Dam than those measures selected for the least cost alternative program and were omitted from consideration for this reason. Salinity control below Hoover Dam, however, is a possible practical approach toward minimizing the economic impact of salinity and should receive further consideration in the formulation of a basinwide salinity control program.

Fluctuations in salinity concentrations resulting from factors such as seasonal changes in stream flow and water use occur throughout the basin. Peak concentrations reached during such fluctuations may exert adverse effects on water use far exceeding the effects predicted on the basis of average salinity conditions. By reducing average salinity levels, a salt load reduction program would provide a moderating effect on such peak concentrations. The possible magnitude of such fluctuations and their adverse impact, however, would indicate the need for more positive means of minimizing peak concentrations. Possible control measures would include the manipulation of reservoir storage and releases, close control of water deliveries to minimize stream fluctuations, and seasonal storage of salts in irrigated areas.

In conclusion, alternative approaches to solution of the Colorado River Basin salinity problem differ greatly in their impact on both basinwide salinity levels and the regional economy. It is clear, however, that regardless of the approach used, the future economic impact of salinity will be great. By timely implementation of salinity controls, it will be possible to minimize this economic impact while holding future increases in salinity levels to a minimum.

Mr. Chairman, at this time Mr. Freeman will conclude the EPA presentation.

MR. STEIN: We are going to have a little change.

Let's have some lights.

I think we are going to call on Mr. Ellis Armstrong now. Mr. Freeman will come later. And there will be one change in the program. Since Mr. Armstrong has to leave, we will open this to questions to him after he concludes.

ELLIS L. ARMSTRONG, COMMISSIONER
BUREAU OF RECLAMATION
U. S. DEPARTMENT OF THE INTERIOR
LAS VEGAS, NEVADA

MR. ARMSTRONG: Mr. Chairman and members of the water quality enforcement conference.

I am delighted to be here today as the representative of the Secretary of the Interior to present the Department's interests and responsibilities in the development and operation of the Colorado River and its position regarding standards for total dissolved solids or salinity, a general term, of course, that we have been using here this morning.

The dissolved solids concentration of the Colorado River is the most difficult water quality problem in the basin and has been for many years. The condition existed before the appearance of man, although it has been accentuated by man's land and water use practices.

Reduction of the TDS concentrations involves complex water resources planning, management, and developmental interrelationships with economic consequences of uncertain magnitude and effect. We believe that numerical dissolved solids standards must be equitable and enforceable, compatible with present and anticipated uses, and based on sound scientific and engineering and cost effectiveness considerations. There must be thorough and positive public participation in the establishment of such standards and in the choice of water quality goals.

And in the context of current and projected conditions within the basin, standards must reflect quality goals as a basis for a practical improvement program aimed at achieving needed salinity control within a reasonable time framework. However and moreover, water quality standards must be adjusted from time to time as improvement programs demonstrate the practicability of dealing with salinity in an economic and beneficial manner.

This Department accepts the need for numerical standards. However, we believe that it would be a premature and poorly defined course of action to apply such standards within a year. It is essential that the available technical knowledge of the physical and social factors involved and their interrelationships and the probable consequences of proposed changes be fully understood before applying numerical standards. Therefore, account should be taken of the salinity control and allied programs of the Bureau of Reclamation, the Office of Saline Water and other agencies in the Department of the Interior and with the States involved in the establishment of these standards. We are developing a mathematical simulation model and have related

E. L. Armstrong

economic studies and several feasibility investigations to assist in the selection process under way. A Federal-State task force should be appointed to provide guidance and to participate in the effort. The task force should be allowed 3 years to complete the work, to complete its findings, and to make recommendations to another session of this conference.

This recommendation is based on these considerations:

1) Historical records at Imperial Dam show that the average salinity concentration for January 1957 was 1,000 ppm and for December 1967 it was 992 ppm or mg/l. Six other months in the period 1941 to 1968 have had average concentrations above 960 ppm. However, it is not possible to predict future salinity concentrations for any particular month, nor can it be assumed that past flow and concentration cycles will probably be repeated in the future.

With Lake Powell and Lake Mead regulating the Colorado River, it would require several consecutive low-flow, that is drought, years to produce an annual salinity concentration of 1,000 ppm,or higher, at Imperial Dam. However, with present depletions, it is probable that the average concentrations for the 8 months referred to above would have exceeded 1,000 ppm. Furthermore, with present depletions, the 1,000 ppm mean monthly concentration at Imperial Dam would have been exceeded in 40 months during the period 1941 to 1968.

2) A number of projects, particularly those involving transmountain diversions, have recently been completed or are now under construction, which will increase the consumptive use of Colorado River water and cause a reduction in dilution flows, which will increase the salinity concentration. Other projects will be undertaken in the near future. These include both Federal projects and those contemplated by municipalities and private industry. Many of these projects could be affected by numerical standards.

The estimated depletions from these projects are listed in the Bureau of Reclamation's report entitled, "Quality of Water-Colorado River Basin-Progress Report No. 5, January 1969." And that summary table is attached to this statement.

If a numerical standard of 1,000 ppm maximum monthly average is established at Imperial Dam, it will probably be necessary to maintain--

MR. STEIN: Mr. Armstrong, do you mean 1969 or 1971?

MR. TABOR: The text says 1971.

MR. ARMSTRONG: Excuse me. Oh, the report?

MR. STEIN: Yes.

MR. ARMSTRONG: It is 1971. Excuse me.

MR. STEIN: O. K. Go on.

MR. ARMSTRONG: I am sorry.

If a numerical standard of 1,000 ppm maximum monthly average is established at Imperial Dam, it will probably be necessary to maintain the 28-year average annual salinity concentration at Imperial Dam for present development, and that is 865 ppm. In order to maintain this concentration with the expected depletions from future projects, a reduction of 2.55 million to 3.0 million tons of salt per year at Hoover Dam will be necessary. If the salinity control projects, described later in my statement, achieve an estimated potential reduction of 1.9 million tons per year at Hoover Dam, and allowing for the depletions by future projects, the 28-year average annual and peak monthly concentrations at Imperial Dam for three levels of reduction would be as shown in Table 1.

And that shows that the annual salt reduction at Hoover Dam for 1.9 million tons, the 28-year average annual concentration at Imperial Dam would be 1,040,or 1 million and 40 tons, and the probable peak concentration would be greater than about 1,160. And then going down with no reduction, for instance, you see that it increases in the annual concentration, the peak monthly concentration at Imperial Dam out in the lower right-hand corner would be 1,360 (sic).

Lights, please.

3)An adequate system of salinity improvement projects will require considerable time--this is the third point--considerable time for formulation and construction. Additional time would then be required before salinity control effects were achieved. In the meantime, the depletions of water mentioned previously will be taking place.

4) Present estimates of the effectiveness of control measures may be optimistic and may have to be scaled down.

5) Numerical standards at points in the system other than at Imperial Dam (assuming smaller numerical limits would be established at upstream points) should be established so as to recognize the physical and hydrological interrelationships of the entire river system.

The Department of the Interior is pledged to pursue a program of salinity control for the benefit of all citizens to whom the Colorado River is a lifeline.

The Secretary has broad as well as specific responsibilities under applicable laws to manage the water resources of the Colorado River Basin to (1) apportion the water flows according to the Colorado River Compact of 1922, (2) meet commitments to Mexico under the International Water Treaty of 1944, (3) conform to the requirements of the Supreme Court Decree of 1964, (4) meet specific contractual obligations with water users in the United States, (5) develop and manage water resources in accordance with specific authorizing legislation and in the public interest, (6) protect the recreation, fish and wildlife, and environmental values, and (7) assist in implementing the provisions of the Water Quality Act of 1965 and amendments relating thereto.

MR. STEIN: You know, after reading those seven, Commissioner Armstrong, I am never going to say we have troubles again. (Laughter.)

MR. ARMSTRONG: You have got a good point.

There are many documents that river operations must conform to, including the Colorado River Basin Project Act of 1968. The "Criteria for Coordinated Long-Range Operation of Colorado River Reservoirs, 1970, these were developed in accordance with this act.

Within the context of these responsibilities and legal requirements there are certain considerations that are paramount, and they include: (1) There can be wide fluctuations in the concentration of dissolved solids in the river as a result of annual variations in precipitation and the management of the available water resources, (2) the total available water resources of the river are allocated by interstate compacts and the international treaty, (3) the treaties and decrees have apportioned water quantitatively but are silent on water quality, and (4) studies made by this Department, the Environmental Protection Agency, the Colorado River Board of California, and the Water Resources Council project increases in salinity unless control measures are taken concurrent with development for use of the presently allocated water.

In recognition of the effects of the proposed developments on the salinity of the river, the Congress specifically directed the Secretary of the Interior to make water quality studies and to devise plans for improvement. This is provided for in three public laws:

1) Section 15 of the authorizing legislation for the Colorado River Storage Project and Participating Projects states and I quote,

> The Secretary of the Interior is directed to continue studies and make reports to the Congress and to the States of the Colorado River Basin on the quality of water of the Colorado River.

2) Section 15 of the authorizing legislation of the San Juan-Chama Project and the Navajo Indian Irrigation Project states:

> The Secretary of the Interior is directed to continue his studies of the quality

> of the water of the Colorado River system, to appraise its suitability for municipal, domestic, and industrial use, and for irrigation in various areas of the United States in which it is proposed to be used, to estimate the effect of additional developments involving its storage and use (whether heretofore authorized or contemplated for authorization) on the remaining water available for use in the United States, to study all possible means of improving the quality of such water, and of alleviating the ill effects of water of poor quality, and to report the results of his studies and estimates to the 87th Congress and every 2 years thereafter.

We have thus far made five reports and this one is the fifth one, dated January 1971, and I think all of you folks have a copy of that report. If not, we will be glad to provide you with one.

3) Authorizing legislation for the Fryingpan-Arkansas--here is another requirement--Fryingpan-Arkansas Project contains similar language pertaining to water quality reports and stipulated that the first report should be provided by January 3, 1962, to be followed by submission of reports

every 2 years thereafter.

These acts provide authority to this Department for basinwide planning of a salinity control program. Implementation of feasible and justifiable salinity control projects will require congressional authorizations. The responsibility to plan and implement the control programs has been entrusted to the Bureau of Reclamation, with the function to be coordinated with other agencies of the Department of the Interior, such as the Office of Saline Water, the Office of Water Resources Research, the Geological Survey, Bureau of Land Management, the Bureau of Indian Affairs, Bureau of Sport Fisheries and Wildlife, Bureau of Outdoor Recreation, and the Bureau of Mines. As planning and implementation progress it is expected that particular contributions can be made by each of these agencies to the successful conduct of the comprehensive program for salinity control.

The Office of Saline Water will be deeply involved in implementing the program. The OSW is currently testing a concept of using a large-scale ion exchange desalting system to control the salinity level of the Colorado River. If this concept proves feasible, OSW, in conjunction with the Bureau of Reclamation, proposes to plan and site a large-scale research and development facility for the purpose of identifying the costs involved in desalting point sources.

The Office of Water Resources Research will assist in the solution of problems that are beyond current technology. The physical and institutional complexities encountered in controlling salinity in the Colorado River appear, from current studies, to be much greater than experienced elsewhere. This will require a push into new technical areas that will require supporting research. In conjunction with the Office of Water Resources Research,requisite technology is being identified and arrangements will be made for prosecution of such research. And these will be subsequently described in greater detail.

The Bureau of Land Management will be involved in programs aimed at increasing water yield, decreasing erosion, subjecting springs and other natural water sources which are unusually high in salinity to control measures, and managing the Lower Colorado Recreation Area to protect the water resources.

Working with the Bureau of Indian Affairs and the Indian tribes, all of whom have a direct concern in the impact of increased salinity levels, means will be explored for reducing salinity contributions from irrigable lands under their jurisdiction. Moreover, the Bureau of Indian Affairs will continue programs for improving the vegetative cover and watershed management to reduce erosion and transmission of sediment in the runoff water from their lands. Here again, cooperation with Indian landowners will be actively sought, since they must determine the measures possible and the rate of accomplishment within available funding.

The Geological Survey has made contributions to the definition of the problem. Its extensive water quality data information system and network in the Colorado River Basin is providing a log of information upon which design and evaluation of water quality programs must be based. Its research into geochemical relationships within the basin should yield important facts useful in planning for and implementing control measures.

Implementation plans will be coordinated with the Bureau of Sport Fisheries and Wildlife and the Bureau of Outdoor Recreation. It is quite possible that beneficial use of saline resources could be accomplished through development of fish and wildlife or recreational areas.

The Bureau of Mines may be called upon to provide assistance in the extraction of mineral of commercial value from the saline waters removed from the river. This could involve studies of processing and use of the minerals and related economic evaluations. Also it has a role in identifying potential sources of salinity increase that may result from mineral extraction processes.

At its headwaters the Colorado River has a total dissolved solids concentration of about 50 ppm or less. As the water moves downstream, as has been described, through this vast arid region, there is a gradual increase in the salinity until at the lower reach at Imperial Dam the long-term average annual values resulting from present development are at a level of about 865 ppm. Much of this increase in salinity occurs as a result of natural solute erosion. This process embraces the geochemical reactions that take place as water moves through the cycle. The process has been active over geologic time. Even with the extensive developments by man, the natural processes are still the principal source of the salinity in the river.

Development of the water resources in the Upper Colorado River Basin took place gradually from the beginning of settlement around 1860 and has been continuing. The principal water use was for irrigation, and by 1905 about 800,000 acres were irrigated. Between 1905 and 1920 the development of irrigated land continued and by 1920 1.4 million acres were irrigated. Development then leveled off and the increase since that time has been slow. In 1965 there were 1.6

million acres under irrigation in the Upper Basin. The slow growth of the irrigated acreage in the Upper Basin in the last 45 years is ascribed to both the physical and economic limitations on the availability of water. By 1920 most of the lower cost and more easily constructed developments were in operation, and although some new developments have taken place since that time, they have been partially offset by other acreages going out of production.

Irrigation development in the Lower Basin also began around 1860. Here the development was slow because of difficult diversions from the Colorado River with its widely fluctuating flow. Development of the Gila area began in 1875 and in the Palo Verde area in 1879, increased in the period 1900 to 1910 with construction of the Yuma Project, the Palo Verde Canal, and other irrigation projects along the river. Completion of the Boulder Canyon Project in the 1930's and construction of other downstream projects since that time have brought about 1,300,000 acres under irrigation. In this regard, the Colorado River now provides 75 percent of the water to southern California where more than half of that State's 20 million people live.

Recognition of the potential water quality problems was made as early as 1903, when the initial work to identify desirable salinity levels for maintenance of crop production under irrigation was undertaken. At that time a limited amount of water sampling and analysis of the river was being performed, primarily by the Geological Survey. The main purpose of early tests was to evaluate the suitability of the water supply for irrigation and other uses. In time it became quite clear that there had been a gradual increase in the salinity as a result of development of the resources.

Salt-concentrating effects were produced by evaporation, transpiration, and diversion of high quality water out of the basin. Also, salt-loading effects occurred through the addition of dissolved solids to the river system from both natural and manmade sources. Because of the wide fluctuations in concentration from natural causes, the developments on the river, particularly the larger reservoirs, produced offsetting beneficial effects by stabilizing the quality of water.

Prior to the passage of the Colorado River Storage Project and Participating Projects, the San Juan-Chama Project and the Navajo Indian Irrigation Project, and the Fryingpan-Arkansas Project, it was evident that these major actions would result in increased consumptive use of the water in the Upper Colorado River Basin as well as water diversion from the basin and thus significant increases in salinity levels could be expected.

Congress directed that specific studies be made of the water quality problem and that control plans be developed in deference to the concern of the people of the basin and the users of the Colorado River water.

As a result of the legislative requirements, a basic network of water quality stations was established at principal points throughout the Colorado River Basin. Analyses and studies were begun for the entire basin, biennial reports were started in 1963 and have continued since, and I mentioned the Report No. 5 which was published in 1971. This report is submitted as a part of this testimony and it covers the basic studies and evaluations of existing salinity conditions, the anticipated effects of additional developments, the effect of salinity on water use, the potentials for salinity control, and other related water quality aspects.

The Colorado River Basin Water Quality Control Project was established in 1960 by the U. S. Public Health Service. These functions were later transferred to the Federal Water Quality Administration within the Department of the Interior and subsequently transferred to the Environmental Protection Agency. The early project investigations assisted in identifying many of the water quality problems of the Basin. In 1963 efforts were directed towards evaluating the salinity problems.

E. L. Armstrong

In 1968 the FWQA and the Bureau of Reclamation initiated a joint reconnaissance salinity control study in the Upper Basin to identify potential controllable sources of salinity, make preliminary assessments of the technical feasibility of the control measures, and derive initial cost estimates for installation and operation of such measures. The first year of the study was financed by the FWQA, which transferred funds to the Bureau of Reclamation, and the second year of work was financed by the Bureau. Upon completion of the reconnaissance studies, FWQA proposed to finance feasibility studies; however, budget limitations in Fiscal Year 1970 prevented funding of these studies.

Also in 1968, the two agencies cooperated to develop a proposed salinity control plan of study for the Colorado River Basin. This initial program had an investigation phase spread over a 6-year period, with costs averaging about $1.75 million a year. The second phase was to involve implementation of a basinwide salinity control plan. During the Federal reorganization activities which transferred the responsibilities of FWQA of the Department to the newly established Environmental Protection Agency, the program became inactive.

Subsequently, the Colorado River Board of California undertook studies of the salinity problem and issued a report in 1970 entitled "Need for Controlling the Salinity of the Colorado River." The Environmental Protection Agency recently completed a report that has been discussed here today. It was this report, entitled "The Mineral Quality Problems in the Colorado River Basin," dated 1971, which set the stage for this conference.

Under the direction of the Water Resources Council, a State-Federal interagency group prepared a framework program for the development and management of the water and related land resources of the Lower Colorado River Region. This report recognized the salinity problem in the basin and recommended continuing studies of the Region's increasingly complex water quality problems. Concurrently, the Bureau of Reclamation, with the assistance of the several States involved, developed a program for investigating methods of controlling the salinity of the river. The funding of this work was accomplished during the current fiscal year. It is currently under way and details will be discussed.

Now, the progress reports by the Bureau of Reclamation, the Salinity Report by the Colorado River Board of California, the Lower Colorado Region Comprehensive Framework Study by the Water Resources Council, and the EPA report, have served to identify and better define the problems involved. The important fact emerging is that salinity is projected to increase with development unless a comprehensive, basinwide water quality management plan is implemented and supported by the installation of structural and nonstructural measures to control salinity increases. Projected estimates of salinity levels at Imperial Dam are presented in Table 2.

May we have the lights, please.

The projected salinity levels in all studies are considerably above the annual average mean for the present development of 865.

Notice the first one is the EPA estimate, 1980--1,060, and 2010--1,220.

The Colorado River Board of California, 1980--1,070, and 2000--1,340,and 2030--1,390.

The Water Resources Council, 1980--1,260, 2000--1,290, 2020--1,350.

And the Bureau of Reclamation study with full development of the authorized projects would be from 1,150 to 1,250.

Now, the difference in these is concerned primarily with the basic assumptions on which the studies were made, that is the rate in which the developments would occur, and while there are some differences in the totals, they all indicate that we do have a problem, as of course we are all aware.

Lights, please.

It is significant that all the studies of the agencies predicted the proposed development will cause a considerable increase. We should also remember that with the present qualities some irrigators are resorting to special practices in order to use the water to grow salt-sensitive crops. Some areas have drainage problems which could be magnified if higher salinity water were used. Municipal and industrial users are now faced with considerable expense in treating water. It is clear that allowing the salinity of the river to increase will result in considerable economic injury. Thus, the salinity problem is primarily an economic issue.

No detrimental effects on the environment along the Colorado River are envisioned due to increased salinity concentrations, that is within the limits expected. Most of the natural vegetation has a salinity tolerance higher than the projected salinity concentrations.

The Department concurs in the EPA's findings that future salinity concentrations will be below threshold levels for instream uses such as recreation, hydroelectric power, fish life.

The prior studies of water quality problems in the Colorado River by the Bureau, the EPA, and the

Colorado River Board of California have served to define the problem and outline potential control measures. They are not, however, sufficient to undertake immediate construction of control measures. Cost effectiveness analyses have been prepared, but these, it must be recognized, are based on reconnaissance studies and reconnaissance data.

For example, point sources of salinity have been geographically identified, salinity concentrations measured, and output of salt load estimated. Neither the feasibility of capturing these flows has been verified by requisite field geological explorations nor the consequence of such proposed actions assessed. Similarly, diffuse sources of salinity have been located but reliable measures of salt loading could not be made because of inadequate records. However, practical methods for controlling the salt loading from such sources still need to be developed.

With respect to the salt loading from irrigated lands, it is anticipated that improvement in management and use of water on the irrigated farms will result in improved quality of return flow. Such action, buttressed by improvements in water conveyance systems, involving seepage reduction through canal lining, and improvement in operational techniques, also is expected to contribute towards reduced salt loadings in the river.

Complex interrelationships of human activities and physical field conditions must be analyzed to determine the amount of salt load reduction that could be achieved. Cooperative research on this problem is under way by the Bureau of Reclamation with the Environmental Protection Agency financing. This work involves the development of a mathematical model for predicting quality of return flows.

Studies by the Bureau of Reclamation have shown that the average annual salt output from irrigation in the basin will occur within the range 0 to 2 tons per irrigated acre. Local irrigated areas overlying marine shales containing large quantities of soluble salts may have annual outputs exceeding 2 tons per irrigated acre, while areas covered with a salt-free loessial mantle overlying the glaciofluvio deposits have practically no salt pickup.

In view of the foregoing, it is essential that feasibility studies be pursued on point, diffuse, and irrigation sources to disclose the maximum improvement in water quality that can be achieved with present technology. These studies must develop the full costs involved, identify the control means, the trade-offs, and specify the time required to achieve specific degrees of control for particular reaches of the river. The comprehensive salinity control plan, therefore, must be engineeringly feasible, politically acceptable, and administratively viable through appropriate institutions.

The program for improvement of water quality that we have under way. Studies recently completed by the Bureau of Reclamation, the Environmental Protection Agency and its predecessors, and the Colorado River Board of California have set the stage for these detailed investigations. Working with several of the States involved, a comprehensive program was launched this fiscal year by the Bureau of Reclamation. The goal of the program is to control salinity of the river at a level compatible with the uses to which that water is and will be put. However, the implementation will be dependent upon the development of economically and environmentally feasible plans and related financing.

The details relating to this program are contained in the February 1972 report of the Bureau entitled "Colorado River Water Quality Improvement Program." This report will be submitted as part of the testimony of this Department. So I am just going to give a brief overview of the program.

Currently the program is funded for this year at $455,000 with a proposed expansion next year of a little over $1 million. The planning activities as scheduled in Fiscal Year 1972 through 1981 total approximately $18 million.

Construction activities which may be initiated within this time frame could involve costs of $300 million or more. Such funding would be requested following a demonstration of economic feasibility of specific salinity control projects. The most promising prospects for achieving salinity control have been screened and therefore effort will be concentrated on feasibility investigations to expedite movement of salinity control projects through the congressional authorization processes.

In the evaluation of this program, a mathematical model of the Colorado River will be developed, and is under development, to analyze the economic costs of salinity versus the cost of salinity control measures. And in this study we will build on the mathematical model work that has been done by the EPA. A study will be conducted to analyze existing institutional and legal requirements. These would form the basis for applying systems analysis to evaluate and select control measures by measuring their physical and economic impacts and assisting in evaluating water management procedures.

In addition, a special study is being made of the potential application of the ion exchange process for desalting the river flows. This will provide assessment of alternative salinity control concepts which have not heretofore been contemplated--that is, controlling salinity on a large scale at diversion points rather than control at the sources. Other supporting studies will be conducted to evaluate still other potential control procedures.

Decision points will be utilized in the program to determine direction as feasibility studies are completed. Salinity control on the scale contemplated represents a pioneering effort in which alternative solutions will need to be assessed for effectiveness, environmental consequences, economic impact, and equitability to the States involved. Also it should be recognized that studies in the reach from Hoover Dam to Imperial Dam have heretofore been insufficient to completely identify the comparatively large increases in salinity occurring within that reach. In the water years 1961 through 1965, the mean concentration below Hoover Dam was 714 ppm while at Imperial Dam for the same period the mean value was 824, an increase of 110. It is essential, therefore, that the salinity problems in this reach be identified. Such additional studies could significantly alter the course of the study.

The point source control program involves evaluation of the control projects at La Verkin Springs, Paradox Valley--these were discussed in the EPA discussion--Crystal Geyser,Glenwood Springs, Blue Springs, and Littlefield Springs. Feasibility studies of point sources are under way at La Verkin

Springs and Crystal Geyser in Utah, Paradox Valley and Glenwood Springs in Colorado. And the Blue Springs in Arizona that I have on my statement will not start until next year, that is the feasibility of that study. Reports are scheduled to be completed for La Verkin Springs and Crystal Geyser in Fiscal Year 1973 and for Paradox Valley and Glenwood-Dotsero Springs in Fiscal Years 1975 and 1976. The physical setting of Blue Springs suggests that development of a control plan may be very difficult, because this is a very complex area and we need additional detailed information, and these studies from the feasibility grade are not scheduled for completion until Fiscal Year 1978 because of the need of additional time to assemble additional basic data. A feasibility study for Littlefield Springs is scheduled for the period 1974 through 1976.

Authorization and funding of the feasible projects are estimated to take 12 to 18 months under the most favorable conditions. With this optimistic assumption, La Verkin Springs and Crystal Geyser could be under construction in 1975. Construction starts on Paradox Valley and Littlefield Springs could begin in 1977 and on the Glenwood Springs in Fiscal Year 1978, and construction on Blue Springs perhaps in 1980.

Of these various point sources, it appears that early results in salinity control could be attained at Crystal Geyser and La Verkin Springs. It is for this reason that these are being pushed early in the program.

Now, the diffuse control projects which provide most favorable prospects for salinity control include the Price River, San Rafael River, Dirty Devil River, McElmo Creek, and Big Sandy Creek. These projects have not as yet been sufficiently studied to formulate more than tentative plans for which costs have not been estimated. The basic concept to be employed is to selectively remove more saline flows from the stream and then to desalt or perhaps some method of evaporation, or partial evaporation. The irrigated areas on these streams would also be investigated to determine if water system improvement and management programs or irrigation scheduling might contribute towards reduction of the salt load.

Basic data collection for diffuse source control projects under way on the Price and San Rafuel Rivers in Utah and Big Sandy Creek in Wyoming. In 1973 basic data collection is scheduled to start on Dirty Devil River in Utah and McElmo Creek in Colorado. Feasibility studies are scheduled to begin in 1974 on the Price River and Big Sandy Creek and on the San Rafael River in Fiscal year 1975. Similar studies on Dirty Devil River and McElmo Creek are scheduled for initiation in Fiscal Year 1976. These studies are programmed to be completed in a period of about 3 or 4 years.

Now, from the standpoint of the irrigation source control projects. The principal irrigated areas contributing salt are the Grand Valley and Lower Gunnison basins in Colorado, Uintah Basin in Utah, the Colorado River Indian Reservation and the Palo Verde Irrigation District lands in Arizona. The program contemplates conducting on-farm irrigation scheduling and water management, coordinated with water systems improvement and management programs within each of the areas.

The on-farm activities would be aimed at reducing the volume of deep percolation to the groundwater regime through--that is where these saline geological formations are present. It is expected that such a reduction would reduce the salt load being introduced into the Colorado River and no doubt some water savings would result. It would also provide increased net returns to the irrigators through greater yields, improved crop quality and lower production costs. The primary technique to be employed is to schedule times and amounts of water to be applied to crops by utilizing some type of a computer program. By developing an accurate water budget and giving operational considerations to the root zone reservoir, a basis is provided for attaining much higher irrigation efficiencies.

Research completed indicates that improved on-farm management of water is likely to be among the least expensive methods of reducing salinity levels. Therefore, work on irrigation scheduling and management is beginning in the Grand Valley Basin this year and will be continued through Fiscal Year 1978. Critical problems are involved in selling the program to irrigators, training personnel, and adapting computer programs for operation in the various areas. Therefore, preparatory activities will be conducted this year and next year for all other areas, with programs then scheduled to be instituted in Fiscal Year 1974 and conducted through Fiscal Year 1978.

Ongoing Bureau of Reclamation research on these procedures suggests that irrigators will immediately benefit from these programs and, therefore, will be willing to adopt and carry them forward after they have been placed in operation. Beyond Fiscal Year 1978, it is contemplated that the various irrigation districts will continue the programs.

An important corollary to on-farm management of water involves improvement of the water conveyance systems to reduce losses and increase operating efficiency. Under certain conditions, this would further curtail salt loading into the river. Engineering studies will be made of the irrigation systems in each of the aforementioned areas to identify the structural measures that will be needed.

Feasibility studies for improvement of water conveyance systems will be under way in the Grand Valley Basin and the Colorado River Indian Reservation in Fiscal year 1972. The latter study is scheduled for completion in 1974 and the former in 1975. Feasibility studies on improvements of irrigation in the Lower Gunnison Basin are scheduled to begin early in Fiscal Year 1973 and completed by 1976. In the Uintah Basin, this activity will encompass Fiscal years 1974 through 1976, and in the Palo Verdo District from Fiscal Years 1974 through 1976. After demonstration of feasibility, congressional authorizations could be sought to instigate construction of the improvements that will be required.

The supporting activities will include the development of a mathematical simulation model of the Colorado River System, further development of economic evaluation methods for water quality, an in-depth study of the institutional and legal problems involved, and the potential application of salinity reduction processes which have not yet been investigated.

Work on the mathematical simulation model is under way and is expected to be completed in Fiscal Year 1973. This will simulate both the quantity and quality conditions of the entire river system. It will become the primary tool for defining operations for salinity control, evaluating impacts of the salinity control projects, and measuring impacts of new irrigation developments on the salinity of the river.

An adjunct to the model will be the economic studies which will provide a base for better deriving economic evaluation procedures for salinity control. In view of the many complexities involved in the assessment of the salinity problem, the development of these tools is regarded as an essential to guide the requirements for prosecution of the program.

Moreover, when developed, the application and results derived from use of these tools must be thoroughly understood by the States and other entities involved with this problem. Once developed, these procedures ought to be utilized and tested by the States involved as an essential prerequisite to the establishment of numerical standards for salinity.

Another study will be conducted of the preliminary feasibility and cost of utilizing large-scale ion exchange systems to control salinity levels on the Colorado River at various points such as Parker or Davis Dam. Salinity reductions would be studied in 100 ppm increments down to a lower limit of 500 ppm. The study involves installation of a small pilot test of applicable ion exchange demineralization processes to the water at Parker Dam. This work is now getting under way by the Office of Saline Water and is scheduled for completion in Fiscal Year 1974. It will provide a test of an alternative concept to the control of salinity at the source.

Based upon the studies accomplished to date, estimates have been made of the potential reductions that could be attained if the point, diffuse, and irrigation source control projects are found to be feasible and are placed into operation. And these are summarized in this table.

The point source control, let's just look at the last two columns, the effect at Hoover Dam in reduction will reduce it 55 ppm, the Imperial Dam 65 ppm.

The diffuse source control would be 30--that is reduce it 30 at Hoover, 35 at Imperial.

Irrigation scheduling would reduce it 50 at Hoover Dam and 65 at Imperial Dam.

For a total reduction of 135 ppm at Hoover, 165 at Imperial.

Lights, please.

In preparing these estimates, potential reductions from improvement of water conveyance systems was not included because effects of such improvement works on salinity reduction have not as yet been sufficiently defined. These estimates are based on reconnaissance studies and will therefore require more detailed information for verification.

The salinity control works could have a major effect in reducing salinity; however, additional elements and concepts will need to be developed and applied if further reductions are to be achieved.

It should be noted that there would be a time lag involved before the influence of the reduction is reflected at points such as Imperial Dam. The large impoundments at Lake Mead and Lake Powell greatly increase the time required for water to travel from the inlet point to discharge at the dam. There are also thermal, density and chemical stratifications that take place in the reservoirs. As a result, periods of 3 to 10 years may be involved before the influence of the control works can be observed at the lower reaches. It follows that the farther downstream the control works are located, the more quickly their impact will be felt.

The investigation program will be financed by the Federal Government under the authority of the laws that I have cited. As feasibility of specific control projects is demonstrated, repayment plans will be developed. It is expected that these will follow established laws and policies relating to the implementation of water resource development projects.

Beneficiaries will need to be identified and cost-sharing formulas worked out. This may require new institutional arrangements not only as they relate to repayment but also to operation and maintenance of the constructed facilities.

The identification of the program components is presented in Figure 1 which is attached to your statement. And then--do we have it? Well, anyway, it is a detailed program, but demonstrates the scheduling of this work that I am going to discuss--excuse me--that I have discussed.

The water quality improvement program may be regarded, of course, as only one facet of the overall development program of the basin. We in the Department believe that water resource management and salinity control are inseparable elements in fostering continued economic growth and development of the resources of the Colorado River Basin.

Salinity control adds another dimension in the preparation of the Western U. S. Water Plan and must be viewed in context with programs for augmentation such as weather modification, geothermal resources, and desalting. From such studies, coordinated through the alternative planning approach, a basinwide management plan for optimum use of the water resources will be evolved.

The basin management system will need to deal squarely with the legal and institutional constraints governing operation of the river, and these are facts of life that must be squarely faced up to. In this regard, it is well to note the recent adoption of "Criteria for Coordinated Long-Range Operation of the Colorado River Reservoirs," that has been adopted. These provide for the storage of water in reservoirs of the Colorado River Storage Project and releases of water from Lake Powell within such constraints and according to certain priorities.

Studies prepared as a basis for formulating these criteria, as well as experience from operating thereunder for more than a year, indicate that such purposes as water quality control, recreation, enhancement of fish and wildlife, other environmental factors, and flood control can be served to some degree without significant detrimental effect on power production and irrigation uses. In particular, such studies indicate that operation for river regulation associated with consumptive uses and power production provide some incidental water quality control and other multiple benefits and allow flexibility for specific short-term operational patterns lasting only a few days for such specific purposes.

Now, the Western U. S. Water Plan. The results from all study activities relating to ongoing Federal and State water resources programs are expected to be utilized in the development--

that is all of these we have been talking about in connection with the salinity and the program--will be utilized in the development of the Western U. S. Water Plan. One of the major efforts of this study is to develop a recommended action program for further comprehensive development of the water resources of the Colorado River Basin and for the provision of additional and adequate water supplies for use in the Upper as well as in the Lower Basin.

Accordingly, these studies will pull together into a basin management system results from ongoing study programs such as weather modification to increase spring runoff in the Colorado River, desalting sea water and brackish water, extraction and desalting of geothermal water, reuse of wastewater, water conservation and salvage, and watershed management. We see that such an augmentation and management program is having an important input towards alleviating future water quality problems.

To demonstrate the application of reverse osmosis technology to the reduction of salinity at point sources in the Colorado River drainage, it is planned to design, construct, and operate a multi-modular plant at a site to be determined by reconnaissance investigations which are scheduled for completion in Fiscal Year 1973. The design of this prototype plant will be based on the best reverse osmosis desalting technology available. Design and construction of the prototype plant could be undertaken during Fiscal Years 1974 and 1975. In subsequent years, studies would be made of the application of the technology to specific point source salinity locations within the Colorado River Basin.

The prototype plant would be sized for 15 million gallons per day and is planned to be on stream in Fiscal Year 1976. The reverse osmosis process lends itself to the construction of added modular units to fit the demonstrated need.

In the area of weather modification, given an applied research and engineering effort to refine and confirm present cloud-seeding techniques and provide analysis of parameters in storms pertinent to a fully identified seeding criteria, a continuous operation could be initiated in the Upper Colorado River Basin conservatively within 10 years. And on the basis of the results of the first 2 years of operating the pilot study in the San Juan Mountains, this could be stepped up perhaps to 6 years. This would involve seeding within well-defined and localized target areas by remote-controlled ground-based generators using silver iodide, and seeding susceptible winter storms at high elevations to increase the winter snowpack.

In a limited area, such as the Colorado River Basin, the production of about 2 million acre-feet of usable new water annually could be a significant contribution towards our salinity improvement problem.

The flexibility of use, largely with existing water and power systems, and the opportunity for obtaining an even greater new water yield with advanced technology point to weather modification as a very desirable tool for water resources management. The Upper Colorado River Basin would be one of the first regions where a reliable optimized capability to increase precipitation would be developed on a regionwide basis. It is believed that firm acceptable answers and workable systems could be successfully achieved within 10 years, and as I indicated, on the basis of continued favorable results from our pilot project we could probably lop 3 or 4 years off of that.

The potential of geothermal resources is currently under investigation by the Bureau of Reclamation and the Office of Saline Water. Successful development will provide energy and an additional source of water supply. The geothermal supply and water could be meshed into the overall water management system to assist in achieving salinity control, particularly in the lower reaches of the system.

The joint Bureau of Reclamation and Office of Saline

Water Geothermal Resource Investigation Program in the Imperial Valley will enter a new phase in this year. Following more than 3 years of geophysical prospecting, coupled with shallow exploratory drilling, the first deep well capable of producing hot steam will be drilled starting in April. It will be located in the East Mesa area of Imperial Valley and drilled to a depth of 4,000 to 8,000 feet. A portable pilot desalting plant will be moved to the well site and test operations for desalting geothermal brines and also a test disposal well is anticipated for late in 1972 to determine the feasibility of reinjecting the byproduct fluids from the geothermal development.

Preliminary studies indicate the Imperial Valley geothermal resources would be capable of producing 2.5 million acre-feet of freshwater per year on a sustaining basis as well as large quantities of electric energy with possible mineral byproduct recovery.

And we have just completed a development concept report on the geothermal resources in the valley, and we will supply each of you with a copy of this report.

Various aspects of the Bureau of Reclamation's operation and maintenance activities deal directly with the salinity problems in the Colorado River. Water quality studies are continuing in the basin as required under various public laws, and biennial reports are made to Congress. These are prepared in cooperation with the Geological Survey. The reports include data regarding historical, present, modified, and anticipated future chemical quality of water conditions at 17 key stations in the Colorado River Basin. Also presented are discussions of State standards, quality control, sources of salinity, sources of other forms of pollution, and other aspects of water quality in the basin. In Fiscal year 1973, $90,000 will be used in prosecution of this program.

Consumptive use studies are being undertaken as required by Section 601 of the Colorado River Basin Project Act. These will provide useful input to prosecution of the salinity control program.

In the area of research, considerable work will be required to support the water quality improvement program in the basin. Ongoing and scheduled research which is expected to find application in the salinity control effort now under way or scheduled by the Bureau of Reclamation include:

1) Prediction of the quality of return flows (in cooperation with EPA);

2) Mathematical model for predicting nutrient and salt loadings;

3) Ecological considerations in project planning;

4) Wastewater reclamation opportunities;

5) Case studies of desalting for salinity control;

6) Management of saline waters; and

7) Testing advanced irrigation systems.

In addition, considerable additional research ought to be performed to assist in implementing a viable salinity control program. As I mentioned, the Office of Water Resources Research is supporting activities in this area, and it is strongly recommended that the Environmental Protection Agency join in financing such efforts. The land grant universities and the Agricultural Research Service of the Department of Agriculture should also have important inputs, and they have today.

Some of the kinds of work needed are: field trials of water harvesting techniques; developing special uses for water of inferior quality; reducing costs for attaining high irrigation efficiencies; identifying field relationships for irrigation efficiency to return flow quality; studies of water flow through large impoundments, including the chemical reactions and velocity of throughput of the dissolved constituents; vegetative management techniques, particularly as related to phreatophytes, with the aim of reducing water use and protecting the breeding areas of birds and other wildlife; identification of watershed management and salinity output relationships; further studies into the economics of water quality; ecological considerations involving salinity effects on aquatic life and other biological systems; recovery and extraction of minerals from brines; development of better inland brine disposal techniques; identifying opportunities for using reclaimed wastewater to satisfy outdoor recreation needs; and identifying opportunities for using heated water from desalting installations to extend the recreation season for swimming and other activities.

And these, then, are some of the things that we have under way and have planned, and it is for this reason that the Department takes the position that they have.

That, Mr. Chairman, is my statement.

MR. STEIN: All right.

Without objection, this will be included with the appendices.

Commissioner Armstrong, you have given us a treasure trove of information. Now, I know you have expanded and I think that this part should be in. But there is some material that you went over rather rapidly. With your permission, I would like to put your full statement in the record as if read.

MR. ARMSTRONG: All right. Thank you.

MR. STEIN: Thank you.

(The statement and appendices referred to follow:)

For release to PM's newspapers, Tuesday, February 15, 1972

UNITED STATES DEPARTMENT OF THE INTERIOR POSITION STATEMENT
PROCEEDINGS OF THE WATER QUALITY ENFORCEMENT CONFERENCE
Presented by Ellis L. Armstrong, Commissioner, Bureau of Reclamation

Las Vegas, Nevada

February 15-17, 1972

Introduction

As the representative of the Secretary of the Interior, I am pleased to present the Department's interest and responsibilities in the development and operation of the Colorado River and its position regarding standards for total dissolved solids, or "salinity," a general term commonly used for this water quality characteristic.

The total dissolved solids concentration of the Colorado River is the most difficult water quality problem in the Basin and has been for many years. The condition existed even before the appearance of man, though it has been accentuated by man's land and water-use practices.

Reduction of the TDS concentrations involves complex water resource planning, management, and developmental interrelations with economic consequences of uncertain magnitude and effect.

This Department states that numerical dissolved solids standards must be equitable and enforceable, compatible with present and anticipated uses and based on sound scientific and engineering and cost effectiveness considerations. There must be thorough and positive public participation in the establishment of such standards and in the choice of water quality goals.

In the context of current and projected conditions within the Basin, standards must reflect water quality goals as a basis for a practical improvement program aimed at achieving the needed salinity control within a reasonable time framework. Moreover, water quality standards must be adjusted from time to time as improvement programs demonstrate the practicality of dealing with salinity in an economic and beneficial manner.

Towards Establishment of Numerical Standards

This Department accepts the need for numerical standards. However, it would be a premature and poorly defined course of action to apply such standards within a year. It is essential that the available technical knowledge of the physical and social factors involved and their interrelationships and the probable consequences of proposed changes be fully understood before applying numerical standards. Therefore, account should be taken of the salinity control and allied programs of the Bureau of Reclamation and the Office of Saline Water and other agencies in this Department and with the States involved in the establishment of the standards. We are developing a mathematical simulation model and have related economic studies, and several feasibility investigations to assist in the selection process underway. A Federal-State Task Force should be appointed to provide guidance and to participate in the effort. The Task Force should be allowed three years to complete the work, to complete its findings, and to make recommendations to another session of this conference.

This recommendation is based on the following considerations:

1) Historical records at Imperial Dam show that the average (parts per million of dissolved solids) salinity concentration for January 1957 was 1,000 mg/l and for **December** 1967 it was 992 mg/l. Six other months in the period 1941-68 have had average concentrations above 960 mg/l. However, it is not possible to predict future salinity concentrations for any particular month, nor can it be assumed that past flow and concentration cycles will probably be repeated in the future.

   With Lakes Powell and Mead regulating the Colorado River, it would require several consecutive low-flow (drought) years to produce an annual salinity concentration of 1,000 mg/l, or higher, at Imperial Dam. However, with present depletions, it is probable that the average concentrations for the 8 months referred to above would have exceeded 1,000 mg/l. Furthermore, with present depletions, the 1,000 mg/l mean monthly concentration at Imperial Dam would have been exceeded in 40 months during the period 1941-68.

2) A number of projects, particularly those involving trans-mountain diversions, have recently been completed or are now under construction which will increase the consumptive use of Colorado River water and cause a reduction in dilution flows which will increase the salinity concentration. Other projects will be undertaken in the near future. These include both Federal projects and those contemplated by municipalities and private industry. Many of these projects could be affected by numerical standards.

The estimated depletions from these projects are listed in the Bureau of Reclamation's report entitled "Quality of Water-Colorado River Basin-Progress Report No. 5, January 1971."

If a numerical standard of 1,000 mg/l maximum monthly average is established at Imperial Dam, it will probably be necessary to maintain the 28-year average annual salinity concentration at Imperial Dam for present development (865 mg/l). In order to maintain this concentration with the expected depletions from future projects, a reduction of 2,550,000 to 3,000,000 tons of salt per year at Hoover Dam will be necessary. If the salinity control projects, described later in this statement, achieve an estimated potential reduction of 1,900,000 tons per year at Hoover Dam, and allowing for the depletions by future projects, the 28-year average annual and peak monthly concentrations at Imperial Dam for three levels of reduction would be as shown in Table 1.

TABLE 1

Annual Salt Reduction at Hoover Dam 1,000 tons	28-Year Average Annual Concentration at Imperial Dam mg/l	Probable Peak Monthly Concentration at Imperial Dam mg/l
1,900	1,040	1,160
1,550	1,075	1,200
1,000	1,135	1,260
No Reduction	1,250	1,370

3) An adequate system of salinity improvement projects will require considerable time for formulation and construction. Additional time would then be required before salinity control effects were achieved. In the meantime, the depletions of water mentioned previously would be taking place.

4) Present estimates of the effectiveness of control measures may be optimistic and may have to be scaled down.

5) Numerical standards at points in the system other than at Imperial Dam (assuming smaller numerical limits would be established at upstream points) should be established so as to recognize the physical and hydrological interrelationships of the entire river system.

The Department is pledged to pursue a program of salinity control for the benefit of all citizens to whom the Colorado River is a lifeline.

Departmental Responsibilities

The Secretary has broad as well as specific responsibilities under applicable laws to manage the water resources of the Colorado River Basin to (1) apportion the water flows according to the Colorado River Compact of 1922, (2) meet commitments to Mexico under the International Water Treaty of 1944 with that nation, (3) conform to the requirements of the Supreme Court Decree of 1964, (4) meet specific contractual obligations with water users in the United States, (5) develop and manage water resources in accordance with specific authorizing legislation and in the public interest, (6) protect the recreation, fish and wildlife, and environmental values, and (7) assist in implementing the provisions of the Water Quality Act of 1965 and amendments relating thereto.

There are many documents that river operations must conform to, including the Colorado River Basin Project Act, September 30, 1968. Criteria for Coordinated Long-Range Operation of Colorado River Reservoirs, June 10, 1970, were developed in accordance with this act.

Within the context of these responsibilities and legal requirements certain considerations are paramount: (1) There can be wide fluctuations in the concentration of dissolved solids in the river as a result of annual variations in precipitation and the management of the available water resources, (2) the total available water resources of the river are allocated by interstate compacts and the international treaty, (3) the treaties and decrees have apportioned water quantity but are silent on water quality, and (4) studies made by this Department, the Environmental Protection Agency, the Colorado River Board of California, and the Water Resources Council project increases in salinity unless control measures are taken concurrent with development for use of presently allocated water.

In recognition of the effects of the proposed developments on the salinity of the river, the Congress specifically directed the Secretary of the Interior to make water quality studies and to devise plans for improvement. This is provided for in three public laws:

1. Section 15 of the authorizing legislation for the Colorado River Stroage Project and Participating Projects states: "The Secretary of the Interior is directed to continue studies and make reports to the Congress and to the States of the Colorado River Basin on the quality of water of the Colorado River."

2. Section 15 of the authorizing legislation of the San Juan-Chama Project and the Navajo Indian Irrigation Project states: "The Secretary of the Interior is directed to continue his studies of the quality of the water of the Colorado River system, to appraise its suitability for municipal, domestic and industrial use, and for irrigation in various areas of the United States in which it is proposed to be used, to estimate the effect of additional developments involving its storage and use (whether heretofore authorized or contemplated for authorization) on the remaining water available for use in the United States, to study all possible means of improving the quality

of such water, and of alleviating the ill effects of water of poor quality, and to report the results of his studies and estimates to the 87th Congress and every 2 years thereafter."

3. Authorizing legislation for the Fryingpan-Arkansas Project contains similar language pertaining to water quality reports and stipulated that the first report should be provided by January 3, 1962, to be followed by submission of reports every 2 years thereafter.

These acts provide authority to this Department for basinwide planning of a salinity control program. Implementation of feasible and justifiable salinity control projects will require congressional authorizations. The responsibility to plan and implement the control programs has been entrusted to the Bureau of Reclamation, with the function to be coordinated with other agencies of this Department such as the Office of Saline Water, the Office of Water Resources Research, the Geological Survey, Bureau of Land Management, the Bureau of Indian Affairs, Bureau of Sport Fisheries and Wildlife, Bureau of Outdoor Recreation, and the Bureau of Mines. As planning and implementation progress it is expected that particular contributions can be made by each of these agencies to the successful conduct of the comprehensive program for salinity control.

The Office of Saline Water will be deeply involved in implementing the program. The OSW is currently testing a concept of using a large-scale ion exchange desalting system to control the salinity level of the Colorado River. If this concept proves feasible, OSW, in conjunction with the Bureau of Reclamation, proposes to plan and site a large-scale research and development facility for the purpose of identifying the costs involved in desalting point sources.

The Office of Water Resources Research will assist in the solution of problems that are beyond current technology. The physical and institutional complexities encountered in controlling salinity in the Colorado River appear, from current studies, to be much greater than experienced elsewhere. This will require a push into new technical areas that will require supporting research. In conjunction with the Office of Water Resources Research requisite technology is being identified and arrangements will be made for prosecution of such research. The research needs will be subsequently described in greater detail.

The Bureau of Land Management will be involved in programs aimed at increasing water yield, decreasing erosion, subjecting springs and other natural water sources which are unusually high in salinity to control measures, and managing the Lower Colorado Recreation Area to protect the water resources.

Working with the Bureau of Indian Affairs and the Indian tribes, all of whom have a direct concern in the impact of increased salinity levels, means will be explored for reducing salinity contributions from irrigable lands under their jurisdiction. Moreover, the Bureau of Indian Affairs will continue programs for improving the vegetative cover and watershed management to reduce erosion and transmission of sediment in the runoff water. Here again, cooperation with Indian landowners will be actively sought, since they must determine the measures possible and the rate of accomplishment within available funding.

The Geological Survey has made contributions to the definition of the problem. Its extensive water quality data information system and network in the Colorado River Basin is providing a log of information upon which design and evaluation of water quality programs must be based. Its research into geochemical relationships within the Basin should yield important facts useful in planning for and implementing control measures.

Implementation plans will be coordinated with the Bureau of Sport Fisheries and Wildlife and the Bureau of Outdoor Recreation. It is quite possible that beneficial use of saline resources could be accomplished through development of fish and wildlife or recreational areas.

The Bureau of Mines may be called upon to provide assistance in the extraction of mineral of commercial value from the saline waters removed from the river. This could involve studies of processing and use of the minerals and related economic evaluations. Also it has a role in identifying potential sources of salinity increase that may result from mineral extraction processes.

The Movement Toward a Comprehensive Salinity Control Program

At its headwaters the Colorado River has a total dissolved solids concentration of about 50 mg/l or less. As the water moves downstream through this vast arid region, there is a gradual increase in the salinity until at the lower reach at Imperial Dam the long-term average annual values resulting from present development are at a level of about 865 mg/l. Much of this increase in salinity occurs as a result of natural solute erosion. This process embraces the geochemical reactions that take place as water moves through the hydrologic cycle. The process has been active over geologic time. Even with the extensive developments by man, the natural processes are still the principal source of the salinity in the river.

Development of the water resources in the Upper Colorado River Basin took place gradually from the beginning of settlement around 1860 and has been continuing. The principal water use was for irrigation, and by 1905 about 800,000 acres were irrigated. Between 1905 and 1920 the development of irrigated land continued at a rapid pace, and by 1920 nearly 1.4 million acres were irrigated. Development then leveled off and the increase since that time has been slow. In 1965 there were 1.6 million acres under irrigation in the Upper Basin. The slow growth of the irrigated acreage in the Upper Basin in the last 45 years is ascribed to both the physical and economic limitations on the availability of water. By 1920 most of the lower cost and more easily constructed developments were in operation, and although some new developments have taken place since that time, they have been partially offset by other acreages going out of production.

Irrigation development in the Lower Basin also began around 1860. Here the development was slow because of difficult diversions from the Colorado River with its widely fluctuating flow. Development of the Gila area began in 1875 and in the Palo Verde area in 1879. The development increased in the period 1900 to 1910 with construction of the Yuma Project, the Palo Verde Canal and intake, and other irrigation projects along the river. Completion of the Boulder Canyon Project in the 1930's and construction of other downstream projects since that time have brought about 1,300,000 acres under irrigation. In this regard, the Colorado River now provides 75 percent of the water to southern California where more than half of that State's 20,000,000 people live.

Recognition of the potential water quality problems was made as early as 1903, with the initial work to identify desirable salinity levels for maintenance of crop production under irrigation. At that time a limited amount of water sampling and analysis of the river was being performed, primarily by the Geological Survey. The main purpose of early tests was to evaluate the suitability of the water supply for irrigation and other uses. In time it became quite clear that there had been a gradual increase in the salinity as a result of development of the water resources.

Salt-concentrating effects were produced by evaporation, transpiration, and diversion of high quality water out of the basin. Also, salt-loading effects occurred through the addition of dissolved solids to the river system from both natural and manmade sources. Because of the wide fluctuations in concentration from natural causes, the developments on the river, particularly the larger reservoirs, produced offsetting beneficial effects by stabilizing the quality of water.

Prior to the passage of the Colorado River Storage Project and Participating Projects, the San Juan-Chama Project and the Navajo Indian Irrigation Project, and the Fryingpan-Arkansas Project, it was evident that these major actions would result in increased consumptive use of the water in the Upper Colorado River Basin as well as water diversion out of the Basin, thereby significant increases in salinity levels could be expected. Congress directed that specific studies be made of the water quality problem and that control plans be developed in deference to the concern of the people of the basin and the users of the Colorado River water.

As a result of the legislative requirements, a basic network of water quality stations was established at principal points throughout the Colorado River Basin. Analyses and studies were begun for the entire Basin, biennial reports were started in 1963, and have continued since that time, with Report No. 5 having been published in 1971. This report is submitted herewith as part of the testimony of this Department. It covers the basic studies and evaluations of existing salinity conditions, the anticipated effects of additional developments, the effect of salinity on water use, the potentials for salinity control, and other related water quality aspects.

The Colorado River Basin Water Quality Control Project was established in 1960 by the U. S. Public Health Service. These functions were later transferred to the Federal Water Quality Administration within the Department of the Interior and, subsequently, transferred to the Environmental Protection Agency. The early project investigations assisted in identifying many of the water quality problems of the Basin. In 1963 efforts were directed towards evaluating the salinity problems.

In 1968 the FWQA and the Bureau of Reclamation initiated a joint reconnaissance salinity control study in the Upper Basin to identify potential controllable sources of salinity, make preliminary assessments of the technical feasibility of the control measures, and derive initial cost estimates for installation and operation of such measures. The first year of the study was financed by the FWQA, which transferred funds to the Bureau of Reclamation, and the second year of work was financed by the Bureau. Upon completion of the reconnaissance studies, FWQA proposed to finance feasibility studies; however, budget restrictions in fiscal year 1970 prevented funding the studies.

Also in 1968, the two agencies cooperated to develop a proposed salinity control plan of study for the Colorado River Basin. This initial program had an investigation phase spread over a 6-year period, with costs averaging about $1.75 million annually. The second phase was to involve implementation of a basinwide salinity control plan. During the Federal reorganization activities which transferred the responsibilities of FWQA of the Department to the newly established Environmental Protection Agency the program became inactive.

Subsequently, the Colorado River Board of California undertook studies of the salinity problem and issued a report in 1970 entitled "Need for Controlling the Salinity of the Colorado River." The Environmental Protection Agency (formerly FWQA) recently completed a report on the studies. It was this report entitled "The Mineral Quality Problems in the Colorado River Basin," dated 1971, which set the stage for the enforcement conference. Under the direction of the Water Resources Council, a State-Federal interagency group prepared a framework program for the development and management of the water and related land resources of the Lower Colorado Region. This report recognized the salinity problem in the Basin and recommended continuing studies of the Region's increasingly complex water quality problems. Concurrently, the Bureau of Reclamation, with the assistance of the several States involved, developed a program for investigating methods of controlling the salinity of the river. The funding of this work was accomplished during the current fiscal year. The work is currently underway and details relating thereto will be subsequently provided.

The progress reports by the Bureau of Reclamation, the Salinity Report by the Colorado River Board of California, the Lower Colorado Region Comprehensive Framework Study by the Water Resources Council, and the EPA report, have served to identify and better define the problems involved. The important fact emerging is that salinity is projected to increase with development unless a comprehensive, basin-wide water quality management plan is implemented and supported by the installation of structural and nonstructural measures to control salinity increases. Projected estimates of salinity levels at Imperial Dam are presented in Table 2. The projected salinity levels in all studies is considerably above the average annual mean for the present development of 865 mg/l.

Table 2

Projected Concentrations of Total Dissolved Solids
(mg/l) at Imperial Dam
(Average annual values)

	Year					
Source	1980	2000	2010	2020	2030	Full Development
EPA	1060	-	1220	-	-	-
CRBC	1070	1340	-	-	1390	-
WRC	1260	1290	-	1350	-	-
USBR	-	-	-	-	-	(1150-1250)

EPA: Environmental Protection Agency
CRBC: Colorado River Board of California
WRC: Water Resources Council (Lower Colorado Region Comprehensive Framework Study)
USBR: Bureau of Reclamation

In developing the above estimates,each agency with the exception of the Bureau of Reclamation, made assumptions regarding the time frame for installation of new water resources development projects. A complete listing of the projects included in the USBR study is attached.

It is significant that all the studies of the various agencies predicted that proposed development will cause a considerable increase in the future salinity of the river. We should also remember,that with the present qualities, some irrigators are resorting to special practices in order to use the water to grow salt-sensitive crops. Some areas have drainage problems which could be magnified if higher salinity water were used. Municipal and industrial users are now faced with considerable expense in treating water. It is clear that allowing the salinity of the river to increase will result in considerable economic injury. Thus, the salinity problem in the Colorado River is primarily an economic issue.

No detrimental effects on the environment along the Colorado River are envisioned due to increased salinity concentration. Most of the natural vegetation has a salinity tolerance higher than the projected salinity concentrations.

The Department concurs in the Environmental Protection Agency's findings that future salinity concentrations in the Colorado River will be below threshold levels for in-stream uses such as recreation, hydroelectric power generation, and propagation of aquatic life.

The prior studies of water quality problems in the Colorado River by the Bureau of Reclamation, the EPA, and the Colorado River Board of California have served to define the problem and outline potential control measures. They are not, however, sufficient to undertake immediate construction of control measures. Cost effectiveness analyses have been prepared, but these, it must be recognized, are based on reconnaissance studies.

For example, point sources of salinity have been geographically identified, salinity concentrations measured, and output of salt load estimated. Neither the feasibility of capturing these flows has been verified by requisite field geological explorations nor the consequence of such proposed actions assessed. Similarly, diffuse sources of salinity have been located but reliable measures of salt loading could not be made because adequate records were not available. Moreover, practical methods for controlling the salt loading from such sources still needs to be developed.

With respect to the salt loading from irrigated lands, it is anticipated that improvement in management and use of water on the irrigated farms will result in improved quality of return flow. Such action, buttressed by improvements in water conveyance systems, involving seepage reduction through canal lining, and improvement in operational techniques, also is expected to contribute towards reduced salt loadings in the river.

Complex interrelationships of human activities and physical field conditions must be analyzed to determine the amount of salt load reduction that could be achieved. Cooperative research on this problem is underway by the Bureau of Reclamation with the Environmental Protection Agency financing. This work involves the development of a mathematical model for predicting quality of return flows.

Studies by the Bureau of Reclamation have shown that the average annual salt output from irrigation in the basin will occur within the range zero to 2 tons per irrigated acre. Local irrigated areas overlying marine shales containing large quantities of soluble salts may have annual outputs exceeding 2 tons per irrigated acre, while areas covered with a salt-free loessial mantle overlying glacio-fluvial deposits have practically no salt pickup.

In view of the foregoing, it is essential that feasibility studies be pursued on point, diffuse, and irrigation sources to disclose the maximum improvement in water quality that can be achieved with present technology. These studies must develop the full costs involved, identify the control means, and trade-offs and specify the time required to achieve specific degrees of control for particular reaches of the river. The comprehensive salinity control plan, therefore, must be engineeringly feasible, politically acceptable, and administratively viable through appropriate institutions.

The Program for Improvement of Water Quality

Studies recently completed by the Bureau of Reclamation, the Environmental Protection Agency and its predecessors, and the Colorado River Board of California have set the stage for more detailed investigations that should lead to early installation of control measures. Working with several of the States involved, a comprehensive program was launched this fiscal year by the Bureau of Reclamation. The goal of the program is to control salinity of Colorado River at a level compatible with the uses to which that water is and will be put. However, the implementation of the program will be dependent upon the development of economically and environmentally feasible plans and related financing.

The details relating to this program are contained in the Bureau of Reclamation February 1972 report entitled "Colorado River Water Quality Improvement Program." This report will be submitted as part of the testimony of this Department. Accordingly, only a brief overview of the program will be discussed here.

Currently the program is funded at a level of $455,000, with a proposed expansion of the program to $1,005,000 in fiscal year 1973. The planning activities as scheduled in fiscal year 1972 through 1981 total approximately $18 million. Construction activities which may be required within this time frame could involve costs of $300 million or more. Such funding would be requested following a demonstration of economic feasibility of specific salinity control projects. The most promising prospects for achieving salinity control have been screened and therefore effort will be concentrated on feasibility investigations to expedite movement of salinity control projects through the congressional authorization processes.

In the evaluation of this program, a mathematical model of the Colorado River will be developed to analyze the economic costs of salinity versus the cost of salinity control measures. A study will be conducted to analyze existing institutional and legal requirements. These would form the basis for applying systems analysis to evaluate and select control measures by measuring their physical and economic impacts, and assisting in evaluating water management procedures.

In addition, a special study is being made of the potential application of the ion exchange process for desalting the river flows. This will provide assessment of alternative salinity control concepts which have not heretofore been contemplated...controlling salinity on a large scale at diversion points rather than control at the sources. Other supporting studies will be conducted to evaluate still other potential control procedures.

Decision points would be utilized in the program to determine direction as feasibility studies are completed. Salinity control on the scale contemplated represents a pioneering effort in which alternative solutions will need to be assessed for effectiveness, environmental consequences, economic impact, and equitability to the States involved. Also it should be recognized that studies in the reach from Hoover Dam to Imperial Dam have heretofore been insufficient to completely identify the comparatively large increases in salinity occurring within that reach. In the water years 1961 through 1965, the mean concentration below Hoover Dam was 714 mg/l while at Imperial Dam for the same period the mean value was 824 mg/l, an increase of 110 mg/l. It is essential, therefore, that the salinity problems in this reach of the river be identified. Such additional studies and testing of new concepts could significantly alter the course of the program.

Point Source Control

The investigation program includes evaluation of point source control projects at LaVerkin Springs, Paradox Valley, Crystal Geyser, Glenwood-Dotsero Springs, Blue Springs, and Little Field Springs. Feasibility studies of point sources are underway at LaVerkin Springs and Crystal Geyser in Utah, Paradox Valley and Glenwood-Dotsero Springs in Colorado, and Blue Springs in Arizona. Reports are scheduled to be completed for LaVerkin Springs and Crystal Geyser in fiscal year 1973 and for Paradox Valley and Glenwood-Dotsero Springs in fiscal years 1975 and 1976, respectively. The physical setting of Blue Springs suggests that development of a control plan may be very difficult. Therefore, these studies are not scheduled for completion until fiscal year 1978. A feasibility study for Littlefield Springs, Arizona is scheduled for the period FY 1974 through FY 1976.

Authorization and funding of the feasible projects are estimated to take 12 to 18 months under the most favorable conditions. With this optimistic assumption, LaVerkin Springs and Crystal Geyser could be under construction in fiscal year 1975. Construction starts on

Paradox Valley and Littlefield Springs could begin in fiscal year 1977 and on Glenwood-Dotsero Springs in fiscal year 1978. Construction on Blue Springs could not begin until 1980.

Of these various point sources, it appears that early results in salinity control could be attained at Crystal Geyser and LaVerkin Springs. It is for this reason that these feasibility studies be completed as rapidly as possible so,if feasible, construction could begin.

Diffuse Source Control

The diffuse source control projects which provide most favorable prospects for salinity control include the Price River, San Rafael River, Dirty Devil River, McElmo Creek, and Big Sandy Creek. These projects have not as yet been sufficiently studied to formulate more than tentative plans for which costs have not been estimated. The basic concept to be employed is to selectively remove the saline (over 1500 mg/l) flows from the stream and then to desalt and/or evaporate the water. The irrigated areas on these streams would also be investigated to determine if water system improvement and management programs or irrigation scheduling might contribute towards reduction of the salt load sufficiently to justify feasibility studies.

Basic data collection for diffuse source control projects is underway on the Price and San Rafael Rivers in Utah and Big Sandy Creek in Wyoming. In fiscal year 1973, basic data collection is scheduled to start on Dirty Devil River in Utah and McElmo Creek in Colorado. Feasibility studies are then scheduled to begin in fiscal year 1974 on the Price River and Big Sandy Creek and on the San Rafael River in fiscal year 1975. Similar studies on Dirty Devil River and McElmo Creek are scheduled for initiation in fiscal year 1976. These studies are programed to be completed in a period of about 3 or 4 years. At this time, it appears that the earliest construction could begin for such projects is fiscal year 1979.

Irrigation Source Control Projects

The principal irrigated areas contributing salt are the Grand Valley and Lower Gunnison basins in Colorado and Uintah basin in Utah; the Colorado River Indian Reservation, and the Palo Verde Irrigation District lands in Arizona. The program contemplates conducting on-farm irrigation scheduling and water management, coordinated with water systems improvement and management programs within each of the areas.

The on-farm activities would be aimed at reducing the volume of deep percolation to the ground-water regime through the saline geologic formations. It is expected that such a reduction in deep percolation would reduce the salt load being introduced into the Colorado River under present conditions. The water savings achieved would become available for other uses. The program would also provide increased net returns to the irrigators through greater yields, improved crop quality and lower production costs. The primary technique to be employed is to schedule times and amounts of water to be applied to crops by utilizing a computer program. By developing an accurate water budget and giving operational considerations to the root zone reservoir, a basis is provided for attaining high irrigation efficiencies.

Research completed indicates that improved on-farm management of water is likely to be amoung the least expensive methods of reducing salinity levels. Therefore, work on irrigation scheduling and management is beginning in the Grand Valley Basin this fiscal year, and would be continued through fiscal year 1978. Critical problems are involved in selling the program to irrigators, training personnel, and adapting computer programs for operation in the various areas. Therefore, preparatory activities will be conducted in fiscal years 1972 and 1973 for all other areas, with programs then scheduled to be instituted in fiscal year 1974 and conducted through fiscal year 1978.

Ongoing Bureau of Reclamation research on these procedures suggests that irrigators will immediately benefit from these programs and therefore will be willing to adopt and carry them forward after they have been placed in operation. Beyond fiscal year 1978, it is contemplated that the various irrigation districts would continue the programs.

An important corollary to on-farm management of water involves improvement of the water conveyance systems to reduce losses and increase operating efficiency. Under certain conditions, this would further curtail salt loading into the river. Engineering studies will be made of the irrigation systems in each of the aforementioned areas to identify the structural measures needed.

Feasibility studies for improvement of water conveyance systems will be underway in the Grand Valley Basin and the Colorado River Indian Reservation in fiscal year 1972. The latter study is scheduled for completion in fiscal year 1974 and the former in fiscal year 1975. Feasibility studies on improvements of irrigation systems in the Lower Gunnison Basin are scheduled to begin in fiscal year 1973 and completed in fiscal year 1976. In the Uintah Basin, this activity would encompass fiscal years 1974 through 1976, and in the Palo Verde District from fiscal years 1974 through 1976. After demonstration of feasibility,congressional authorizations could be sought to initiate construction of the improvement works.

Support Activities

The supporting activities will include the development of a mathematical simulation model of the Colorado River System, further development of economic evaluation methods for water quality, an in-depth study of the institutional and legal problems involved, and the potential application of salinity reduction processes which have not been previously investigated.

Work on the mathematical model is currently underway and is scheduled for completion in fiscal year 1973. The model will simulate both the quantity and quality conditions of the river system. It will become the primary tool for defining operations for salinity control, evaluating impacts of the salinity control projects and measuring impacts of new irrigation developments on the salinity of the river.

An adjunct to the model will be the economic studies which will provide a basis for better deriving economic evaluation procedures for salinity control. In view of the many complexities involved in the assessment of the salinity problem, the development of these tools is regarded as an essential guiding requirement for prosecution of the salinity control program.

Moreover, when developed, the application and results derived from use of these tools must be thoroughly understood by the States and other entities involved with this problem. Once developed, these procedures ought to be utilized and tested by the States involved as an essential prerequisite to the establishment of numerical standards for salinity.

A parametric study will be conducted of the preliminary feasibility and cost of utilizing large-scale ion exchange systems to control salinity levels on the Colorado River at various points such as Parker or Davis Dam. Salinity reductions would be studied in 100 mg/l increments down to a lower limit of 500 mg/l. The study involves installation of a small pilot test of applicable ion exchange demineralization processes to the water at Parker Dam. This work is now getting underway by the Office of Saline Water and is scheduled for completion in fiscal year 1974. It will provide a test of an alternative concept to the control of salinity at the source.

Program Impacts

Based upon the studies accomplished to date, estimates have been made of the potential reductions that could be attained if the point, diffuse, and irrigation source control projects are found to be feasible and are placed into operation. The results are summarized in Table 3.

Table 3

Summary
Water Quality Improvements

Practive	Present Associated mineral load (1000's tons/yr)	Estimated Reduction (1000's tons/yr)	Effect at Hoover Dam (mg/l)	Effect at Imperial Dam (mg/l)
Point Source Control	1,385	745	-55	-65
Diffuse Source Control	945	390	-30	-35
Irrigation Scheduling Scheduling	2,370	680	-50	-65
Totals	4,700	1,815	-135	-165

In preparing these estimates, potential reductions from improvement of water conveyance systems was not included because effects of such improvement works on salinity reduction have not as yet been sufficiently defined. These estimates are based on reconnaissance studies and will therefore require more detailed study for verification.

The salinity control works could have a major effect in reducing salinity; however, additional elements and concepts will need to be developed and applied if further reductions are to be achieved.

It should be noted that there would be a time lag involved before the influence of the reduction is reflected at points such as Imperial Dam. The large impoundments such as Lake Mead and Lake Powell greatly increase the time required for water to travel the distance from the inlet plint to discharge at the dam. Also, thermal, density and chemical stratification take place. As a result, periods of 3 to 10 years may be involved before the influence of the control works can be observed at the lower reaches. It follows that the farther downstream the control works are located, the more quickly their impact will be felt.

Program Financing and Repayment

The investigation program will be financed by the Federal Government under the authority of laws previously cited herein. As feasibility of specific control projects is demonstrated,repayment plans will be developed. It is expected that these will follow established laws and policies relating to the implementation of water resource development projects. Beneficiaries will need to be identified and cost-sharing formulas worked out. This may require new institutional arrangements not only as they relate to repayment but also to operation and maintenance of the constructed facilities.

Program Schedule

The identification of the program components is presented on Figure I attached.

Allied Programs

The water quality improvement program as described above may be regarded as one facet of the overall development program of the basin. This Department believes that water resource management and salinity control are inseparable elements in fostering continued economic growth and development of the resources of the Colorado River Basin.

Salinity control adds another dimension to the preparation of the Western U. S. Water Plan and must be viewed in context with programs for augmentation such as weather modification, geothermal resources, and desalting. From such studies, coordinated through the alternative planning approach, a basin-wide management plan for optimum use of the water resources will be evolved.

The basin management system will need to deal squarely with the legal and institutional constraints governing operation of the river. In this regard, it is well to note the recent adoption of "Criteria for Coordinated Long-Range Operation of the Colorado River Reservoirs." These criteria provide for the storage of water in reservoirs of the Colorado River Storage Project and releases of water from Lake Powell within such constraints, and according to certain priorities.

Studies prepared as a basis for formulating these criteria, as well as experience from operating thereunder for more than a year, indicate that such purposes as water quality control, recreation, enhancement of fish and wildlife, other environmental factors, and flood control can be served to some degree without significant detrimental effect to power production and irrigation uses. In particular, such studies indicate that operation for river regulation associated with consumptive uses and power production provide some incidental water quality control and other multiple benefits, and allow flexibility for specific short-term operational patterns lasting only a few days for such purposes.

Western U. S. Water Plan

The results from all study activities relating to ongoing Federal and State water resources programs are expected to be utilized in the development of the Western U. S. Water Plan. One of the major efforts of this Westwide Study is to develop a recommended action program for further comprehensive development of the water resources of the Colorado River Basin and for the provision of additional and adequate water supplies for use in the Upper as well as the Lower Basin.

Accordingly, these studies will pull together into a basin management system results from ongoing study programs such as weather modification to increase spring runoff in the Colorado River, desalting sea water and brackish water, extraction and desalting of geothermal water, reuse of wastewaters, water conservation and salvage, and watershed management. We see that such an augmentation and management program as having important inputs towards alleviating future water quality problems.

Desalting

To demonstrate the application of reverse osmosis technology to the reduction of salinity at point sources in the Colorado River drainage basin, it is planned to design, construct, and operate a multi-modular plant at a site to be determined by reconnaissance investigations scheduled for completion in fiscal year 1973. The design of this prototype plant will be based on the best reverse osmosis desalting technology available. Design and construction of the prototype plant could be undertaken during fiscal years 1974 and 1975. In subsequent years, studies would be made of the application of the technology to specific point source salinity locations within the Colorado River Basin.

The prototype plant would be sized for 15 million gallons per day (MGD). This 15-MGD plant is planned to be on stream in fiscal year 1976. The reverse osmosis process lends itself to the construction of added modular units to fit the demonstrated need.

Weather Modification

Given an applied research and engineering effort to refine and confirm present cloud-seeding techniques and provide analysis of parameters in storms pertinent to a more fully identified seeding criteria, a continuous operation could be initiated in the Upper Colorado River Basin within 10 years. This would involve (1) seeding within well-defined and localized target areas by remote-controlled ground-based generators using silver iodide, and (2) seeding susceptible winter storms at high elevations to increase winter snowpack.

In a limited area, such as the Colorado River Basin, the production of about 2 million acre-feet of usable new water annually could be a significant contribution towards salinity improvement.

The flexibility of use, largely with existing water and power systems, and the opportunity for obtaining an even greater new water yield with advanced technology point to weather modification as a very desirable tool for water resources management. The Upper Colorado River Basin would be one of the first regions where a reliable optimized capability to increase precipitation would be developed on a region-wide basis. It is believed that firm acceptable answers and workable systems could be successfully achieved within 10 years.

Geothermal Resources

The potential of geothermal resources is currently under investigation by the Bureau of Reclamation and the Office of Saline Water. Successful development will provide energy and an additional source of water supply. The geothermal energy and water could be meshed into the overall water management system to assist in achieving salinity control, particularly in the Lower reaches of the system.

The joint Bureau of Reclamation and Office of Saline Water Geothermal Resource Investigation Program in the Imperial Valley, California, will enter a new phase in 1972. Following more than 3 years of geophysical prospecting, coupled with shallow exploratory drilling (to 1,500 feet), the first deep well capable of producing hot steam and brine will be drilled in April. The well will be located in the East Mesa area of Imperial Valley and drilled to a depth of 4,000-8,000 feet. A portable pilot desalting plant will be moved to the well site and test operations for desalting geothermal brines will start. Also, a test disposal well is anticipated for late in 1972 to determine the feasibility of reinjecting the byproduct fluids from geothermal development.

Preliminary studies indicate the Imperial Valley geothermal resources might be capable of producing 2,500,000 acre-feet of fresh water per year on a sustained basis as well as large quantities of electric energy with possible mineral byproduct recovery.

Operation and Maintenance Activities

Various facets of the Bureau of Reclamation's operation and maintenance activities deal directly with salinity problems in the Colorado River. Water quality studies are continuing in the basin as required under various public laws, and biennial reports are made to Congress. These reports are prepared in cooperation with the Geological Survey. The reports include data regarding historical, present, modified, and anticipated future chemical quality of water conditions at 17 key stations in the Colorado River Basin. Also presented are discussions of State standards, quality control, sources of salinity, sources of other forms of pollution, and other aspects of water quality in the basin. In fiscal year 1972, $90,000 will be used in prosecution of this program.

Consumptive use studies are being undertaken as required by Section 601 of the Colorado River Basin Project Act. These studies will provide useful input to prosecution of the salinity control program. In fiscal year 1972, $100,000 is being expended for this activity.

Research

Considerable research will be required to support the water quality improvement program in the basin. Ongoing and scheduled research which is expected to find application in the salinity control effort now underway or scheduled by the Bureau of Reclamation include: (1) Prediction of the quality of return flows (in cooperation with EPA), (2) mathematical model for predicting nutrient and salt loadings, (3) ecological considerations in project planning, (4) wastewater reclamation opportunities, (5) case studies of desalting for salinity control, (6) management of saline waters, and (7) testing advanced irrigation systems.

In addition to the foregoing research, considerable additional research ought to be performed to assist in implementing a viable salinity control program. As previously indicated, the Office of Water Resources Research is supporting activities in this area, and it is strongly recommended that the Environmental Protection Agency join in financing such research efforts. The land grant universities and the Agricultural Research Service of the Department of Agriculture should also have important inputs.

Some of the kinds of work needed are field trials of water harvesting techniques, developing special uses for water of inferior quality; reducing costs for attaining high irrigation efficiencies; identifying field relationships of irrigation efficiency to return flow quality;

studies of water flow through large impoundments including the chemical reactions and velocity of throughput of the dissolved constituents; vegetative management techniques particularly as related to phreatophytes with the aim of reducing water use and protecting the breeding areas of birds and other wildlife; identification of watershed management and salinity output relationships; further studies into the economics of water quality; and ecologic considerations involving salinity effects on aquatic life and other biological systems; recovery and extraction of minerals from brines; development of better inland brine disposal techniques; identifying opportunities for using reclaimed waste water to satisfy outdoor recreation needs; and identifying opportunities for using heated water from desalting installations to extend the recreation season for swimming and other activities.

FIGURE 1

COLORADO RIVER

WATER QUALITY IMPROVEMENT PROGRAM

PROJECTS	1972	73	74	75	76	77	78	79	80	81
POINT SOURCE CONTROL PROJECTS										
La Verkin Springs	░	░		▥	▥	▥	▥			
Paradox Valley	░	░	░	░		▥	▥	▥	▥	
Crystal Geyser	░	░		▥	▥					
Glenwood-Dotsero Springs	░	░	░	░	░		▥	▥	▥	▥
Blue Springs		░	░	░	░	░	░		▥	▥
Littlefield Springs			░	░		▥	▥	▥		
DIFFUSE SOURCE CONTROL PROJECTS										
Price River	▨	▨	░	░	░	░		▥	▥	▥
San Rafael River	▨	▨	▨	░	░	░		▥	▥	▥
Dirty Devil River		▨	▨	▨	░	░	░		▥	▥
McElmo Creek		▨	▨	▨	░	░	░		▥	▥
Big Sandy Creek	▨	▨	░	░	░	░		▥	▥	
IRRIGATION SOURCE CONTROL										
IRRIGATION SCHEDULING & MANAGEMENT										
Grand Valley Basin	▥	▥	▥	▥	▥	▥	▥	*		
Lower Gunnison Basin			▥	▥	▥	▥	▥	▥	*	
Uintah Basin			▥	▥	▥	▥	▥	*		
Colo. River Indian Reservation			▥	▥	▥	▥	▥	*		
Palo Verde Irrigation District			▥	▥	▥	▥	▥	*		
WATER SYSTEMS IMPROVEMENT & MGT.										
Grand Valley Basin	░	░	░	░		▥	▥	▥	▥	▥
Lower Gunnison Basin		░	░	░	░		▥	▥	▥	▥
Uintah Basin			░	░	░		▥	▥	▥	▥
Colo. River Indian Reservation	░	░	░		▥	▥	▥	▥	▥	▥
Palo Verde Irrigation District			░	░	░		▥	▥	▥	▥
SUPPORT STUDIES										
Mathematical Model of Colorado River	▥	▥								
Economic Evaluation of Water Quality	▥	▥	▥	▥	▥					
Institutional & Legal Analysis	▥	▥								
Ion Exchange Process Systems	░	░	░		▥	▥	▥	▥	▥	▥

DATA COLLECTION ▨

FEASIBILITY ░

▥ CONSTRUCTION or COMPLETION ACTIVITY

* DISTRICTS OPERATE PROGRAM

Projects depleting Colorado River water

Project and state	New depletion (ac.-ft.)	New irrigation land (acres)
Above the gage Green River at Green River, Wyoming		
Seedskadee, Wyoming	145,000	58,000
Westvaco and others, Wyoming	86,000	1/
Between the above gage and the gage Green River near Greendale, Utah		
Lyman, Wyoming	10,000	0
Utah Power & Light and others, Wyoming	8,000	1/
Above the gage Duchesne River near Randlett, Utah		
Central Utah Project, Utah		
Bonneville Unit	166,000	2/
Upalco Unit	10,000	0
Uintah Unit	30,000	7,800
Between the gages Green River near Greendale, Utah, and Duchesne River near Randlett, Utah, and the gage Green River at Green River, Utah		
Four County, Colorado	40,000	2/
Hayden Steamplant, Colorado	12,000	1/
Cheyenne-Laramie, Wyoming	24,000	2/
Savery-Pot Hook, Colorado-Wyoming	27,000	17,920
Central Utah Project		
Jensen Unit	15,000	440
Above the gage San Rafael near Green River, Utah		
Utah Power & Light, Emery County, Utah	5,000	1/
Above the gage Colorado River near Glenwood Springs, Colorado		
Denver-Englewood, Colorado	216,000	2/
Green Mountain M&I, Colorado	12,000	1/
Homestake Project, Colorado	49,000	2/
Between the above gage and gage Colorado River near Cameo, Colorado		
Independence Pass Expansion, Colorado	14,000	2/
Fryingpan-Arkansas, Colorado	70,000	2/
Ruedi M&I, Colorado	38,000	1/
West Divide, Colorado	76,000	19,000
Above the gage Gunnison River near Grand Junction, Colorado		
Fruitland Mesa, Colorado	28,000	15,870
Bostwick Park, Colorado	4,000	1,610
Dallas Creek, Colorado	37,000	15,000
Between the gages Colorado River near Cameo, Colorado, and Gunnison River near Grand Junction, Colorado, and the gage Colorado River near Cisco, Utah		
Dolores, Colorado	3/140,000	32,000
San Miguel, Colorado	85,000	26,000
Above the gage San Juan River near Archuleta, New Mexico		
San Juan-Chama, New Mexico	110,000	2/
Navajo Indian Irrigation, New Mexico	4/508,000	110,000
Between the above gage and the gage San Juan River near Bluff, Utah		
Animas-La Plata, Colorado-New Mexico	146,000	46,500
Expansion Hogback, New Mexico	10,000	0
Utah Construction Co., New Mexico	25,000	1/
Return flow--Dolores and Navajo Indian Irrigation, Colorado and New Mexico	-311,000	3/ 4/
Between the gages Green River at Green River, Utah; San Rafael River near Green River, Utah; Colorado River near Cisco, Utah; and San Juan River near Bluff, Utah; and the gage Colorado River at Lees Ferry, Arizona		
Resources, Inc., Utah	102,000	1/
Arizona M&I, Arizona	35,000	1/
Salvage	-80,000	
Subtotal Upper Basin	1,892,000	350,140
Between the above gage and the gage Colorado River near Grand Canyon, Arizona	0	0
Above the gage Virgin River at Littlefield, Arizona		
Dixie Project, Utah	5/48,000	6,900
Between the gages Colorado River near Grand Canyon, Arizona, and Virgin River at Littlefield, Arizona, and the gage Colorado River below Hoover Dam, Arizona-Nevada		
Southern Nevada Water Project, Nevada	6/240,000	1/
Between the above gage and the gage Colorado River below Parker Dam, Arizona-California		
Fort Mohave and Chemehuevi Indian, Arizona, California, and Nevada	83,000	20,900
Central Arizona, Arizona7/	433,000	
Reduced Metropolitan Water District Diversions7/	-433,000	
Kingman, Arizona	18,000	1/
Mohave Valley I&D District, Arizona	6,000	1/
Lake Havasu I&D District, Arizona	7,000	1/
Salvage	-87,000	
Reduced Metropolitan Water District Diversions7/	-199,000	
Between the above gage and the gage Colorado River at Imperial Dam, Arizona-Colorado		
Colorado River Indian, Arizona-California	243,000	60,840
Salvage	-104,000	
Subtotal Lower Basin	255,000	88,640
Total Colorado River	2,147,000	438,780

1/ In-basin depletion without irrigated lands.

2/ Transmountain diversion.

3/ In-basin transfer from Dolores River drainage to the San Juan River drainage--estimated 53,000-acre-foot return flow to the San Juan River.

4/ Diversions at Navajo Reservoir, estimated 258,000-acre-foot return flow to the San Juan River below the gage near Archuleta, New Mexico.

5/ Includes a transmountain diversion to Great Basin.

6/ Pending full development, the Mohave Thermal Plant will use part of this water which will be diverted below Hoover Dam.

7/ The Central Arizona Project diversions will vary, depending on the depletions by other projects on the river. Under present modified conditions maximum diversions to Central Arizona could be 2,172,000 acre-feet but with full depletions by the projects tabulated, the maximum diversions would be 433,000 acre-feet. Also with full depletions by the projects tabulated, the diversions to the Metropolitan Water District of Southern California would be reduced to an annual 550,000 acre-feet from its present diversions of 1,182,000 acre-feet. This will provide 199,000 acre-feet needed to develop the other tabulated projects in the Lower Basin in addition to the 433,000 acre-feet delivered to the Central Arizona Project.

MR. STEIN: Are there any questions or comments?

MR. THATCHER: Mr. Chairman.

MR. STEIN: Yes.

MR. THATCHER: He mentioned a February 1972 report of the Bureau. Will the conferees get copies of this?

MR. ARMSTRONG: We will have that for you--
How soon will--

MR. STEIN: Is that Report No. 5? I had that noted too.

MR. ARMSTRONG: No, no. The Report No. 5 is the January 1971 report, which you have. The report that you are referring to is now in the process of being put together, and we will have it to you within 30 days, and as soon as we can get it to you. It is in the final stages of being put together.

MR. STEIN: Mr. Thatcher?

MR. THATCHER: Yes.

MR. STEIN: What do you think we should do about it, put it in the record?

MR. ARMSTRONG: Yes, sir, I would like it included in the record, if you would, because it includes the details of these things that I have been discussing.

MR. STEIN: When will we have that?

MR. ARMSTRONG: Within 30 days and as soon as we can.

MR. STEIN: All right. Without objection we will put it in the record as if read with--

Do you think we could have enough copies--

MR. ARMSTRONG: We will furnish you whatever copies you like.

MR. STEIN: --to provide the States, because I don't want them to have to wait for the record.

MR. ARMSTRONG: Yes.

MR. STEIN: O. K.?

MR. ARMSTRONG: We will arrange to do that. We will have our staff work with yours to provide whatever copies you need.

(Editor's Note: See p. 16, Reconvened Session, April 26-27, 1972, for the above-mentioned report. See Report #5 appended herein.)

MR. STEIN: Any other comments?

Mr. Dibble.

MR. DIBBLE: Mr. Chairman, I have a question of Commissioner Armstrong.

There are two tables in your report--

MR. ARMSTRONG: Yes.

MR. DIBBLE: --that you presented. One is at page 30, which shows the water quality improvements that would probably be able to be effected from point source controls, both diffuse source controls, and from irrigation scheduling, and you indicate perhaps that perhaps at Hoover the salinity level could be reduced to 135 mg/l. But over on page 5 there is a table which shows the probable concentrations at Imperial Dam. And at page 30 I should have used the Imperial Dam figure of possible reduction of 165.

These figures on Table 1 on page 5 suggest that if there is no salinity reduction the concentration at Imperial Dam would be 1,250.

MR. ARMSTRONG: Yes.

MR. DIBBLE: But if you took out 1.9 million tons of salt at Hoover Dam it would be 1,040, which is a greater salinity reduction.

The figures don't seem to fit together and I was just wondering if someone could look into those and see if they could reconcile them.

MR. ARMSTRONG: They--

MR. DIBBLE: If that is too complicated to try to explain here, maybe--

MR. ARMSTRONG: All right, we will look into it and provide you with an explanation for the record. I don't think there is any problem there. It is a matter of detailed explanation, I think.

MR. DIBBLE: Mr. Chairman, I have one other question--

MR. STEIN: Yes.

MR. DIBBLE: --or really a comment about Mr. Armstrong's statement.

This is an enforcement conference that is called here today, and the first thing you had on your agenda was the uranium tailings and that is clearly an enforcement problem. But it is very clear, as pointed out not only by the EPA staff but by Commissioner Armstrong, that this matter of the salinity problem of the Colorado River is way more than an enforcement problem, In fact, isn't really an enforcement problem at all except from some of the waste discharges from the municipalities and industry.

MR. STEIN: That is what we deal with —— enforcement problems from waste discharges, Mr. Dibble.

MR. DIBBLE: This is a resource management problem and I am glad to see that the Bureau is now beginning to really get this thing in focus. I would just guess that had this conference been a year ago, the Bureau wouldn't have been able to make as strong a statement as it did today of how it expects to be able to move along. I think the Bureau is to be commended for making such a strong statement here today.

I sincerely hope, Mr. Armstrong, that the Bureau will get all the support it needs to carry through on a program such as you are proposing here.

MR. ARMSTRONG: We plan to, yes. Thank you.

MR. DIBBLE: And I think the conference report should do that.

MR. STEIN: Are there any other comments from the States?

Mr. O'Connell?

MR. O'CONNELL: I have a comment and a question.

I note that from your Table 3 you anticipate an improvement in Imperial Dam of 165 ppm and comparing that to the projected degradation in the EPA report by 1980 at Imperial Dam I note that is 191 ppm. It would appear that if the program went in and was completely successful that we would still lose ground between now and 1980. I just wish we could be more optimistic than that.

But then--

MR. ARMSTRONG: Well, they are based on conservative estimates, and we are hoping that they will be better. But at the same time, you will note our estimate of what the full development program is, which is somewhat less than the estimates that you folks made, based on a little different basic assumptions, and this is where the differences arise. We think ours are pretty sound, but there are areas where honest differences of opinion can occur.

MR. O'CONNELL: It would appear on the basis of the best estimates that we can make projecting increases and decreases that over the next 10 years we probably can't hold our own as far as salinity and--

MR. ARMSTRONG: Oh, I am a little more optimistic than that. I think with the, again, good possibilities of the weather modification program making a contribution that this is going to be helpful.

MR. STEIN: Knowing the other conferees, I suspect we all have the same thought. I think the essential thing is that this conference first met in 1960. If you take the EPA statistics as correct, and I assume they are, we have lost ground since 1960. It has gotten progressively worse until 1970. If we are going to roll that back by minus 165, we are still going to be in not as good shape as we were in 1960.

MR. ARMSTRONG: Well, again it ties in to the consumptive use of water. As I have pointed out, there have been additional diversions, and this has been the primary problem. Then, of course, in that period we have had the problem of filling Glen Canyon and some of these other factors that aren't repeating themselves.

MR. STEIN: By the way, I understand the problem, but I think we have to face the public and say we have been here for

10 years--10 years since we had the conference--and salinity is increasing. Yet the kind of program that we have heard here isn't going to roll that back to what it was in 1960. It is going to be over 1,000 at Imperial Dam.

MR. ARMSTRONG: Well, we are hoping. We are hoping, Mr. Chairman, that we can with this program get it back down below that figure. But we think it is premature to say that now until we get this additional information put together and analyzed, because as you well know, there is no magic to this thing, and it is going to take a lot of good, hard slugging work--

MR. STEIN: Darned right.

MR. ARMSTRONG: --on the part of everyone. And as you mentioned at the start of the meeting, our job now is to positively get hold of these problems and get with it and I think that is where we are.

MR. STEIN: While we are this far on it, I am reading possibly from the press release--I think this summarizes your position--where you say that, "It is essential that the available technical knowledge of the physical and social factors involved and their interrelationships and the probable consequences of proposed changes be fully understood before applying numerical standards."

Is that correct?

MR. ARMSTRONG: Yes, I think generally that is it.

MR. STEIN: O. K. And then you say:

"A Federal-State Task Force should be appointed to provide guidance and participate in the effort. The task force should be allowed 3 years to complete the work, to complete its findings and to make recommendations to another session of this conference."

MR. ARMSTRONG: Yes, sir.

MR. STEIN: All right. Well, the point is--I think we are going to have several points. One, the question we are going to have to ask is why we don't have numerical standards now. Secondly, why we should have 3 years. And if we do both, maybe some people want to abolish the conference, and if it is abolished what are you going to have to report to?

It seems to me what your statement assumes is the establishment of a Federal-State task force and the continuance of the conference.

MR. ARMSTRONG: Yes, yes.

MR. STEIN: Unless I misread you.

MR. ARMSTRONG: Yes. Yes.

MR. STEIN: All right.

MR. ARMSTRONG: Yes, this is what we suggest.

MR. STEIN: All right.

MR. ARMSTRONG: And again for the reasons that we pointed out, that the legal problems, the institutional requirements, the river compacts, all the rest of these ramifications of the various laws that I cited, and so on, present a very complex problem. The interstate problems that they have, we think that the States should be involved and working on this task force.

MR. STEIN: No, I understand that. But if the whole thing is going to work, we are going to have to have a conference to report to.

MR. ARMSTRONG: Oh, yes, surely.

MR. STEIN: All right.

MR. ARMSTRONG: Agreed.

MR. STEIN: Yes.

MR. WRIGHT: Mr. Armstrong, I note on page 6 that the Department is pledged to pursue the program of salinity control. I could pledge to take the salt out of the river with a teaspoon and it wouldn't mean a whole lot. Could you tell me the amount of effort and the amount of energy that is at the--the resources that are at the disposal of the Bureau at this point in time?

MR. ARMSTRONG: Well, I pointed out that we have a program now planned of study of $18 million here in the next 7 years which indicates certainly a big effort, and from the standpoint of recognition of this problem by, of course, all the States in the West, and because of the recognition of our overall problem on the Colorado, I anticipate that if we have a good sound case that Congress will appropriate funds to proceed as we come up with these projects that we can recommend for implementation, construction and implementation.

MR. WRIGHT: Mr. Stein, I would just like to echo Mr. Dibble's comments that it does appear that we have the Bureau's attention finally. (Laughter.)

MR. ARMSTRONG: You have had it for at least 2-1/2 years, I can assure you that.

MR. WRIGHT: And it does appear that the problem is mainly a water resources problem, that the individual States are in the process now and always have been of controlling salinity from point sources of industrial discharge and municipal discharge.

MR. ARMSTRONG: Yes.

MR. WRIGHT: And maybe that is where our resources should be at this point.

Thank you.

MR. ARMSTRONG: There has been some discussion on stepping this Fiscal Year 1973 program up. In the budget we have a little better than $1 million and we would be able, if there is that type of support, to step that up and probably double it.

MR. STEIN: Well, this works both ways. I am glad we have the Bureau's attention. We were hampered without them. I love these guys. (Laughter.) I hope they have your attention. The Bureau needs your attention as well as you need theirs.

MR. ARMSTRONG: Believe me, you have.

MR. STEIN: Are there any other comments or questions? Yes.

MR. DICKSTEIN: Mr. Commissioner, it seems to me that there is no question that irrigation is probably one of the major problems in our salinity control program, and you state in the document that improved on-farm management is one of the areas you will be looking at.

MR. ARMSTRONG: Yes.

MR. DICKSTEIN: Now, in your contractual arrangements with the various irrigation ditches, can the Bureau actually regulate the amount of water to the given irrigation ditch where you actually can use possibly better irrigation practices in these areas?

MR. ARMSTRONG: Not to the degree I think that you are referring to, and these types of things are a continuing education type program, demonstration type. As I pointed out, I think it is to everyone's benefit to recognize this and we are getting recognition in most areas.

There are other means to approach this, of course, besides our contractual arrangements.

MR. STEIN: Any others?

MR. WILLIAMSON: Comment, Murray.

Some 5 or 6 years ago when we started talking about possible control projects, always the bugaboo of financing that came up is who is going to pay for it.

MR. ARMSTRONG: Yes, sir.

MR. WILLIAMSON: I noticed in a very brief section in the program financing and repayment that it will follow established laws, and as near as I can see there it is probably going to be a real tough job of who is the beneficiaries of some of these projects. All we can do as States is probably hope you don't try to charge them all back to the irrigation project where they were built because this would put quite a few people out of business. But this is still an unsolved problem, I take it, or one that is--

MR. ARMSTRONG: Well, it is one that is not simple. It is very complex, as I indicated. And this is one of the reasons and this is one of the areas that has got to receive some very detailed analyses and some hard thinking to come up with something, Item 1, that is equitable and, 2, that is attainable. In this field a lot of good wishful thinking is fine, but when you get down to dollars and cents there are some other problems, and this is what we want to do is realistically approach this from the overall standpoint, from the standpoint of the local users and the States and the national interests, to come up with a way of financing it. And this is why we suggest to take this additional time.

MR. STEIN: Any other comments or questions?

MR. O'CONNELL: I have one more.

MR. STEIN: Yes.

MR. O'CONNELL: I notice on your Figure 1, which shows the timing of various projects, that you don't actually show much in the way of construction until about Fiscal Year 1974. I wondered if it would be at all possible if you could consider accelerating some of that by way of, say, demonstration projects, such as the Office of Saline Water project, and so on, to get a few of these perhaps under way in a limited way.

MR. ARMSTRONG: Yes. You see, this gives us time to go ahead and get detailed, and this talks about the actual construction and it takes a little leadtime. We may in one or two instances, for instance, La Verkin Springs, perhaps step it up, and we are looking into that. This is what we think is reasonably possible to accomplish.

MR. STEIN: Are there any other questions?

I have a few.

Let me refer to the pages in your statement. Page 18. You say, "The salinity problem in the Colorado River is primarily an economic issue. No detrimental effects on the environment along the Colorado River are envisioned due to increased salinity concentration."

Do you really mean that?

MR. ARMSTRONG: Within the limitations that we are talking about here, and as I explained further, that is natural vegetation that we are talking about, because natural vegetation has a salinity tolerance higher than the projected salinity concentration--

MR. STEIN: I understand that. But the problem that we are getting at here, and I don't know that we had this, but I suspect we had an economic investigator here in past conferences, Dr. Nathaniel Wollman, who I believe is now Dean of Arts and Sciences at the University of New Mexico. He pointed out that if you used the water in gross regional profit for irrigated agriculture in the States, you were going to get the value of X; if you used it for municipal and industrial use you were going to get 3X; if you used it for recreational use you were going to get 7X.

MR. ARMSTRONG: Yes, sir.

MR. STEIN: The point is, if we are talking in terms of vegetation and we are talking in terms of 7X for recreation, we are talking in terms of different things. And the question is if we are talking about environmental detriment due to increased salinity, I think we have to take other things into account other than the growth of--

MR. ARMSTRONG: Oh, there is no question on that. We are in agreement with that, that this is the--it has to be the entire environment. And that all of these things, of course, have a very complex interrelationship, too, that has to be carefully evaluated and kept in mind.

MR. STEIN: All right.

MR. DIBBLE: Mr. Chairman, may I ask something?

MR. STEIN: Yes.

MR. DIBBLE: May I follow on the question that Mr. O'Connell asked about your scheduling of your programs, and you indicated that perhaps some of these could be expedited. Is there any way that this conference could identify with your help, Mr. Armstrong, which of these things could be expedited, and perhaps this conference could, before it is concluded, take some kind of a position on urging either the Bureau or Congress, I guess Congress, to provide the funding that would be needed to speed up some of these things? Because as has been pointed out here, if some of these things are not speeded up the quality of the river will continue to get worse.

MR. ARMSTRONG: Yes, sir.

MR. DIBBLE: And that is the one thing I think we should pledge ourselves to see does not happen. I think every State has a water quality policy which is against the further degradation of water, and I think we should all try to carry out that policy on the Colorado River.

MR. ARMSTRONG: Well, I think these that we have identified here on this chart can--for instance, the point source control projects could be stepped up some. Well, the whole program. The whole program, it is a massive across-the-board type of approach; the diverse source control projects. The problem there again is getting the basic data on which to come up with some viable method of control.

As I stated, I think on the basis of detailed study, and John, I think you have it here, that we estimate we could step it up double what is in the present President's budget.

Do you have those?

MR. MALETIC: Yes. Would you like me to list those, Mr. Commissioner?

MR. ARMSTRONG: Would you like to give us the details on that? Do you have them, John?

MR. DIBBLE: Well, I am not sure, Mr. Stein, whether Mr. Armstrong can just give it off the cuff.

MR. STEIN: Have you got that?

MR. ARMSTRONG: I have the statement here. Let me give you this.

MR. STEIN: Yes.

MR. ARMSTRONG: It can be accelerated. An evident drawback, as I mentioned, is lack of sufficient data, particularly for diffuse sources, to allow early preparation of feasibility level designs and estimates for the comptrollers. Acceleration can be applied to some point source control, some of the water system improvement and management, the irrigation scheduling and management, the economic evaluations and an early start on several of these new activities such as the dissolving of the return flows from the Palo Verde Irrigation District, Bryan disposal studies in the lower reaches of the Colorado, and an overall salinity source identification study from Hoover to Imperial where I mentioned, you know, that we have rather a large increase in the salinity. In addition, data collection for the diffuse sources could be accelerated. And this was the basis for the additional money that I mentioned.

MR. STEIN: Are there any other comments?

MR. DIBBLE: Thank you.

MR. STEIN: Commissioner Armstrong, I would like to call your attention to page 20, the last paragraph.

> ...it is essential that feasibility studies be pursued on point, diffuse, and irrigation sources to disclose the maximum improvement in water quality that can be achieved with present technology.

MR. ARMSTRONG: Yes, sir.

MR. STEIN: These studies must develep the full costs involved, identify the control means, the trade-offs,and specify the time required to achieve specific degrees of control for particular reaches of the river.

We have been dealing with water quality here and we have argued—and I know you have cost/benefit in the reclamation operation—but where else in pollution control do we deal with the time with the trade-offs, full costs involved, etc.? The judgment we have on water quality under the present law, as I understand it—and this is both State and Federal—is those people who are responsible for it have to clean it up.

MR. ARMSTRONG: And the problem is defining who those folks are in a complex problem as we have here.

MR. STEIN: I don't think we have--

MR. ARMSTRONG: This isn't quite--

MR. STEIN: You have helped us define this.

MR. ARMSTRONG: Yes.

MR. STEIN: And the group here, they have indicated how much came from return flow irrigation and from natural sources. I think you have done a magnificent job on that.

But the question here is whether we adopt a different rule in judging whether these people are going to be responsible for the cleanup on the costs involved and the trade-offs that we don't apply usually to cities or industries.

MR. ARMSTRONG: I see your point. But there are some differences from the pollution in the normal sense, that is other than the return flows from irrigation, and so on, that comes in the picture from industry, but--

MR. STEIN: Here, let me give you page 22, it is the same thing, the same point, last paragraph:

> Such funding would be requested

following a demonstration of economic feasibility of specific salinity control projects.

Suppose that salinity was causing pollution. If we gave that same requirement or same choice to any city or industry we regulate, that they will give us their job for control after they demonstrate the economic feasibility of the project, I wonder how much pollution control we would have had in this country.

MR. ARMSTRONG: I think, Mr. Chairman, what we are talking about here is the degree of what is pollution and how many parts per million added becomes a polluting effect in this area where there isn't any such thing as a black or white line. And it depends on what you are going to do with it and where you are going to use it and where you are on the river and what your particular problems are. So it doesn't quite lend itself to this type of rather more black and white decision that you have in some of the other areas.

MR. STEIN: In other words, what you are suggesting, for the interest or the sources in the Colorado River is use a somewhat different technique than we and the States have been using for other point source discharges?

MR. ARMSTRONG: No, I am not sure that I get your point.

MR. STEIN: Well, we generally don't ask them for a demonstration of economic feasibility.

MR. ARMSTRONG: Well, it would be--you would have to have some very sound reasons to, for instance, follow the--

MR. STEIN: I understand your point.

MR. ARMSTRONG: And we have got to determine what these quality improvements that we are talking about are going to cost and whether or not they have some other side effects from the standpoint of cost that can overbalance, you see, the decrease in salinity. And this is the part--well, this was explained quite well with the report of EPA, some of the complexities of this problem.

MR. DIBBLE: Mr. Chairman, this comes back to the very point I was trying to make at the very start. In enforcement--you have been using this kind of conference, of course, for several years to carry out enforcement--one does go to the matter of waste discharges and the treatment of waste discharges, and the first part of the conference today was about the uranium tailings. And I don't think there is any question in anybody's mind here that the mill owners are being required to stabilize those tailings so as to eliminate the discharge to the river, and there is just no question about that. That is a pollution control measure and there can be enforcement.

Now, the salinity control, on the other hand, really, when you get right down to it, is a management of our water resource and the quality of it separate and apart from enforcement. I take that into account by listening to Commissioner Armstrong and your staff. Maybe we even take salt out of some of these natural sources. You are not going to enjoin those natural sources through any enforcement action (laughter), you are just going to manage it. We have got to spend some money to implement a program to remove that salinity.

And when you start down that path, there clearly have to be some trade-offs, because Congress when it goes to appropriate the money has to recognize that there are some benefits to be derived over and above the costs of the project. And that is something that I think our conference has to get clearly into focus.

MR. STEIN: By the way, I just wanted to raise the question. I don't say I disagree. But I think you have put this into clear focus. What you are suggesting is that we perhaps have a little different rule here than when we are dealing with any point source like a uranium mill or a city or a steel mill or a packinghouse.

MR. ARMSTRONG: Certainly.

MR. STEIN: And I think this is my point in putting this forward.

MR. DIBBLE: Yes.

MR. STEIN: If this is the issue here.

MR. ARMSTRONG: Yes.

MR. STEIN: Now, I have a few more questions that are largely informative. Let's go to page 23.

You talk about controlling salinity on a large scale at diversion points rather than controlling the sources.

MR. ARMSTRONG: Yes, sir.

MR. STEIN: Does this mean that we figure that we are going to have a tributary stream or stretch of stream that is just going to have a high salt and we are just going to forget that and wait until it gets to a diversion point to take it up?

MR. ARMSTRONG: Yes.

MR. STEIN: Generally speaking, and I think this is in the Federal Act, we control pollution at the source. What you are suggesting here is that we have some stretches—and I recognize there are 1,400 or 1,200 miles of the Colorado River main stem and 60 tributaries— what you are suggesting is that we are just going to let some of these main stretches go either on the main stem or tributaries and just pick this up at a diversion source?

MR. ARMSTRONG: No, let me elaborate on that just a bit. What I am saying is this, that all of these things we have to examine and most of them we have to implement. And one way that we can, for instance, reduce some of the losses--and keep in mind, this problem of pollution, I am not sure that that is the right term when you get into the utilization and management of your water resources when you use it for irrigation and for municipal use in the West, because it isn't really a black and white type of thing as to where it becomes pollution and where it isn't-- And so what we are referring to here is a technique that looks to have promise now that we could, say at Imperial Dam, run the water through this ion exchange where we could reduce the salts from, say, 1100 ppm to 900 ppm.

MR. STEIN: But until it gets to Imperial Dam we will just give up that little stretch?

MR. ARMSTRONG: No, no, no, we are not giving it up at all. We are talking about the source where you are going to use it, see, where in that reach, 1,100 ppm is just as good as 900 ppm as far as anything is concerned in that reach. But when we get down to the point where you are going to utilize it, where that degree of salinity is needed or is economically reasonable for that use, then we can run the water through there and take out, say, a couple hundred parts per million.

MR. STEIN: I think you have got to realize that in our program, Mr. Armstrong, the issue again is whenever we are dealing with industries and municipalities, we ask them to treat at the source. What you are suggesting here is that the source be not necessarily the point of treatment. You are going to let that quality of water go down to a particular diversion point which you or we might designate and treat it there, and from there on we are going to improve it.

MR. ARMSTRONG: Yes. But what I am saying, that is a different problem. Keep in mind, before we did any management work on the Colorado, in the late flows, late flows of the summer got up as high as 4,000, 5,000 ppm, and then during the other part of the season it was flood flow and it was no good to anybody. And through management, you see, of a limited renewable resource we have created this vast southwest economy by reason of proper utilization of this basic resource of water.

And so this is quite a little different problem than the one you normally deal with.

MR. STEIN: I understand. And what you are saying is that this is a different problem and we should treat this differently than our ordinary treatment of pollution at the source. And I think the sooner we understand what we are saying the better off we are going to be.

MR. DIBBLE: Mr. Chairman, if I may say so, respectfully, I think you too have perhaps missed the point, because I think the EPA staff and the Bureau both have been trying to identify the sources and are analyzing the cost and the feasibility of treating some of the sources. Now, for instance, Glenwood Springs is an example, way up the river, a big source of salt, and you are looking into the feasibility of actually controlling at the source--

MR. STEIN: No, no, wait, that is another point. I think, sir, what--

MR. DIBBLE: It is not a great deal of difference.

MR. STEIN: I agree with you on that. I think the question I was raising here is that the point was made that we control salinity. I agree, there is no problem, we have no problem on treating at the source at Glenwood Springs. And on page 23 it says we control salinity on a large scale at diversion points rather than control at the sources. Now, this is what I was getting at.

I have no problem with treating Glenwood Springs at the source, but I think I understand what Commissioner Armstrong is saying, and that is at certain places he is not going to treat at the source--

MR. ARMSTRONG: No, no. No, sir, I am not saying that at all. What I am saying is that here is another way that we can approach this.

MR. STEIN: Right.

MR. ARMSTRONG: And with these other things, if we can't get it down to an acceptable salt content, say, for the municipal use in southern California, then there is this additional technique that is now developing of ion exchange of large quantities of water, you see, that may be able at the point of diversion where it takes off for southern California--

MR. STEIN: I understand that.

MR. ARMSTRONG: --take out to--

MR. STEIN: California may be happy, but how about the people that are there until it gets to that point in question?

MR. ARMSTRONG: What I am saying, Mr. Chairman, I pointed out the increase between Hoover Dam and Imperial Dam where the uses are largely for recreation use, fish and wildlife, and so on, and where this 200 ppm doesn't make any difference. You can't measure it as far as those effects are concerned.

The problem in this area is what the standard ought to be, and there isn't any real threshold that we rather loosely discuss because it varies. It varies on what you do with it; it varies on where you are; it varies on what your soil conditions are and the crops and this whole variety of problems, and where you have to—there are places in the United States where they have as much as 2,500 ppm in their municipal water and they think it is great. Well, they have some problems, of course. They would like it if the water wasn't quite so hard, but they live with it.

MR. STEIN: I have never heard of anyone who thought that was great.

MR. ARMSTRONG: Some health addict-- (Laughter.)

MR. STEIN: Let me get to another point and this is largely explanatory.

I think you heard the EPA people say that the largest single source of salinity, natural source, possibly, if we can use that term, not manmade, is Blue Springs.

MR. ARMSTRONG: Yes.

MR. STEIN: --as I read your statement--

MR. ARMSTRONG: Yes, it is Blue Springs.

MR. STEIN: --you said it is not going to be controlled until 1980.

MR. ARMSTRONG: Yes.

MR. STEIN: Dirty Devil, McElmo Creek, Price River, Big Sandy Creek, San Rafael, 1979. In other words, what your program is saying is that these real high concentrations of salts EPA talked about, you don't expect to reduce until the 1980's?

MR. ARMSTRONG: No, sir, I think you miss my point. What we are doing is concentrating on these high concentrations where we have a point source, and then as fast as we can accumulate good sound basic data on these large-scale source areas--this is where the big problem is, you know.

MR. STEIN: No, sir, I don't think I miss your point. Let me refer you to page 25.

MR. ARMSTRONG: All right.

MR. STEIN: "Construction on Blue Springs could not begin until 1980."

MR. ARMSTRONG: That is on the basis of Blue Springs.

MR. STEIN: No, I am not arguing with your presumptions of statement. I think on the next page you talk Dirty Devil--

MR. ARMSTRONG: Yes.

MR. STEIN: --the Price River, Sandy River, Dirty Devil River, McElmo Creek. "At this time, it appears that the earliest construction could begin for such projects is fiscal year 1979."

MR. ARMSTRONG: Yes.

MR. STEIN: I am giving you these statements, this is from your statement.

MR. ARMSTRONG: Yes, sir.

MR. STEIN: Now, the point is EPA indicated that these were the large natural salt well discharges, point discharges. You are saying that your program that you are putting forward, that if we follow this, it is optimistic, rosy, it is rosy hued as you present it, and the best you put it, it is not going to start until--we won't see it until the middle of the 1980's.

MR. ARMSTRONG: Yes, sir.

MR. STEIN: This is just an information question, not an argumentative one, sir.

MR. ARMSTRONG: Well, but let me point out, the point I am trying to make here is that we are concentrating on these areas where we have information and basic information where we can proceed at an early date with the design of the facilities. In these diffuse sources that are mentioned here, while they are big contributors to the salt load, they drain vast areas, you see, and salt is picked up over the whole area and there has to be a lot of better and sounder specific data that we can base an approach on, and this is our problem here. It is not a small job. We are talking about one-twelfth of the areas of the United States that is involved in this thing and the basic data that is needed to--

MR. STEIN: No, I understand what you are saying. I am not arguing that. But the point is we can't expect to get reduction in salt in the Colorado River under your program on these until the 1980's, is that correct, sir?

MR. ARMSTRONG: We can start to have an effect with all of these things as they come into effect, and we are hoping on the basis of what we have that we can hold our own.

(Off the record.)

MR. DIBBLE: Mr. Chairman, the question I asked Mr. Armstrong sometime ago really related to the very point you are making. I said--I didn't say that this program looks awfully slow, but what I said, isn't there some way it could be speeded up and expedited. Commissioner Armstrong said, if I understood him correctly, yes, it could. And he started to name some specific things, but it seemed to me that Mr. Armstrong was saying specifically, yes, the program can be speeded up so that we can get some results in an earlier time frame, which I think are clearly indicated we need.

MR. STEIN: Is that correct, Mr. Armstrong?

MR. ARMSTRONG: Yes.

MR. STEIN: Will you specify on that the area? Do you care to respond to that in detail?

MR. DIBBLE: Did I misunderstand you?

MR. ARMSTRONG: Well, I gave you, Mr. Chairman, a fairly good detailed statement on that. If you would like us to expand it, I would like to do that for the record and we can give you more specifics and I think maybe I should do that.

MR. STEIN: In other words, you think we can reduce the salt before 1980?

MR. ARMSTRONG: Sure, we can do things that will have a reducing effect on the salt from some of these sources.

But I think, again let me emphasize that, gee, there is no magic solution to any of these problems. It is going to take a massive approach clear across the board and all of these are--or probably very few of them are going to have spectacular results. But in the aggregate, though, they will begin to have an effect and that is what we are shooting for. Most promising, I think, in the immediate picture is this weather modification program.

MR. STEIN: O. K. You say that we should have a Federal-State task force, allowed 3 years to complete the work and to make recommendations for Federal--before we have numerical findings?

MR. ARMSTRONG: Yes, sir.

MR. STEIN: Then on page 29 you say:

> Once developed, these procedures ought to be utilized and tested by the States involved as an essential prerequisite to the establishment of numerical standards for salinity.

Is that included in the 3 years?

MR. ARMSTRONG: Yes. We are talking about these models, these models that were being given.

MR. STEIN: Yes.

MR. ARMSTRONG: Yes, sir.

MR. STEIN: In other words, you envision this program with the State testing and everything for 3 years to come up with numerical requirements?

MR. ARMSTRONG: We anticipate to have these mathematical models developed and perfected to the extent that you can determine, then, what specific standards set in different locations, what effect that would have on the overall area. And hopefully also in the economic model, what effect it has economically up and down the Colorado Basin. We think this is quite important. We have a good clear indication of what these effects are going to be at the time you adopt the standards.

MR. STEIN: Are there any other questions or comments? If not, thank you very much.

MR. ARMSTRONG: Thank you.

MR. STEIN: You have made a really profound contribution to the conference.

MR. ARMSTRONG: Thank you.

MR. STEIN: We appreciate this and appreciate the cooperation we always get from the Department of the Interior.

MR. ARMSTRONG: Thank you.

MR. STEIN: Thank you.

Let's stand recessed for 10 minutes.

(RECESS)

MR. STEIN: Let's reconvene.

We will continue with the Federal presentation.

Mr. Dickstein.

MR. DICKSTEIN: Mr. Freeman, please.

MR. WRIGHT: Mr. Stein, may I interrupt just a minute, please?

MR. STEIN: Yes.

MR. WRIGHT: I had several comments during the break that people in the audience did not know who was at the head table. Could we have introductions again?

And also, even though Mr. Armstrong's presentation was very enlightening and quite gutty in terms of this overall program, I did learn to read about sixth or seventh grade and would like to recommend that we change the procedure to summaries of these statements rather than a complete reading of the text. There are about 93 people here and most of them are relatively high salaried people and the cost of such a time-consuming process is quite high. If I could just make that proposal, at any rate.

MR. STEIN: Well, I agree with your proposal. Let me tell you that psychologically and philosophically I agree with you. (Laughter.)

However, if you have ever tried to have anyone have a summary, you know how difficult it is. And I don't think this is the case with something like Mr. Armstrong's statement, because really some of the material we got here is information that I have been waiting to hear for years. But sometimes, and I really don't mean to say this as a criticism, sir, just as an experience, I know with citizens groups I have tried over and over again when the people come in and someone has a statement to ask them to summarize. When they have prepared their full statement and you ask them to summarize and they don't do this professionally, perhaps as you and I might, you throw them into a tailspin. I think the fastest way to get these things through is let everyone state it in his own manner.

Now, I really do wish that I knew how to do what you suggest, because I couldn't agree with you more. But I have never found a way.

Mr. Freeman, did you hear those sound words of advice? (Laughter.)

MR. FREEMAN: Yes, sir. Does that mean I can speak at my own rate of speed? (Laughter.)

MR. STEIN: No. I tell you this, though, what is the highest priority of this operation. The thing we are doing is making a record and without the court stenographer you are not going to have a record. She is the most precious thing here, so act accordingly.

MR. FREEMAN: Yes, sir.

RUSSELL FREEMAN
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MR. FREEMAN: We have just a few more brief comments to summarize from our presentation and then we will turn to the findings, conclusions and recommendations of the report.

The preceding speakers for EPA defined present and expected future physical and economic impacts of salinity. They also addressed some attention to technical solutions for the salinity problem. These discussions point out the need to set objectives for future water quality and to formulate a basinwide salinity control plan to meet these objectives. Such a plan was presented and described by Mr. Vincent in one appendix to the report being presented.

In the initial process of establishing water quality standards pursuant to the Federal Water Quality Act of 1965, salinity standards were not established, primarily due to a lack of information. Salinity levels which could be maintained by implementing controls were not known. More significantly, the economic effects of maintaining any given salinity level were also unknown. The project investigations and related research and demonstration activities and the studies of others which have been conducted concurrently have now provided much needed new information. Although additional effort will be required to establish detailed basinwide criteria which are equitable, workable and enforceable, present information is considered adequate to form the basis for the establishment of a salinity objective which will set an upper limit on salinity increases at key locations throughout the Colorado River.

Due to the scale and types of control projects included in the salt load reduction program, an approach similar to that utilized for authorization and funding of water resource development has been considered as most appropriate for this control program. Water resource projects normally move through three basic steps before they are placed in operation. A project is first authorized by Congress on the basis of preliminary plans developed by limited studies known as reconnaissance studies. Following authorization, funds may be appropriated for more detailed planning investigations, known as feasibility studies. A feasibility report is then submitted to Congress and construction funds are requested. The third step begins when funds are appropriated for construction. Completion of a construction activity then places the project in operation.

Frequently a number of related projects are authorized by a single legislative act, as was in the case for the Colorado River Storage Project Act, which authorized several large reservoirs at one time. It is recommended that this approach be used for the entire basinwide salinity control program.

One other point to consider is the ongoing research and demonstration activities which have been carried on while the salinity control program was in operation. A number of research and demonstration activities are discussed in Chapter V of this report. These research activities are directed toward improvement of salinity control technology. Completion of such activities will need to be provided--I am sorry, let me start that statement again. Completion of these activities will be needed to provide the technology needed for control of all types of salinity sources. Additional research may also be required if certain types of salinity sources are to be controlled.

The greatest lack of available technology, as we see it now, is in the area of controlling natural diffuse sources of salinity. This means that in order to complete the salinity control program on a reasonably tight time schedule it will be necessary to complete research and demonstration activities which are presently under way in a timely manner. This fact, coupled with the time span required for completion of most research efforts, indicates the need for early initiation of any additional needed research or demonstration activities.

Mr. Chairman, that concludes the summary of information in our report, and I would turn at this time to a brief summary of the project's findings, and then I will present the recommendations with a brief discussion of each recommendation.

The findings are described on page 5 of the summary document report, for those of you who would like to follow as I present them. And again I will be summarizing.

The first finding is that salinity is the most serious water quality problem presently existing in the Colorado River Basin. Average annual salinity concentrations in the Colorado River presently range from less than 50 ppm in the high mountain headwaters to about 925 ppm at Imperial Dam, the last point of major water diversion in the United States. Salinity adversely affects the water supply for a population exceeding 10 million people and for 800,000 irrigated acres located in the Lower Colorado River Basin and the southern California water service area. Salinity also adversely affects water uses in Mexico and in limited areas of the Upper Colorado River Basin.

The second finding is that salinity concentrations in the Colorado River system are affected by two basic processes. These are the salt loading or addition of mineral salts from various natural and manmade sources and the salt concentrating process. That is the loss of water from the system through evaporation, transpiration and out-of-basin export.

The third finding is that salinity and stream flow data used in the 1942 to 1961 period of hydrologic record were used as a basis for estimating average salinity concentrations under various conditions of water development and use. Assuming repetition of this hydrologic record, salinity concentrations at Hoover Dam would average about 760 mg/l under 1970 conditions. If development and utilization of the basin's water resources proceed as proposed and if no salinity controls are implemented, average annual salinity concentrations at Hoover Dam would increase to about 990 mg/l in the year 2010.

The present annual economic detriments of salinity are conservatively estimated to be $16 million. If no salinity controls are implemented, it is estimated that the average annual economic detriments measured in 1970 dollars will increase to about $51 million by 2010.

Alternatives exist for salinity control in the Colorado River Basin, including the alternative of augmenting the water supply, reducing the salt load or limiting further development of the basin's water supplies.

Our finding is that a basinwide salt load reduction program appears to be the most feasible of the three salinity control alternatives. The scope of such a program will depend upon the desired salinity objectives. Partial implementation of the other two alternatives would increase the effectiveness of the salt load reduction program.

Based on those findings, the EPA report contains three specific recommendations. I would like to present and discuss those recommendations briefly.

The first recommendation, which will be found on page 8 of the summary report, is that a salinity policy be adopted

R. Freeman

for the Colorado River system that would have as its objective maintenance of the salinity concentrations at or below levels presently found in the lower main stem. This recommendation refers to the lower main stem, but a broader application of the policy should be inferred. Control of quality in the lower main stem requires that effective controls be applied throughout the Colorado River Basin. In this sense, then, the recommendation is intended for application throughout the Colorado River system.

Our second recommendation is that specific water quality standards criteria be adopted at key points throughout the basin by appropriate States, in accordance with the Federal Water Pollution Control Act. And let me discuss just the first sentence of that recommendation briefly.

The Federal Water Pollution Control Act amendments of 1965 called for the establishment of standards in all interstate waters. The seven States of the Colorado River Basin in 1967 requested that setting of salinity standards on the Colorado River be deferred pending completion of ongoing studies by the Bureau of Reclamation and the Federal Water Pollution Control Administration. The Secretary of the Interior, recognizing the complexity of the situation, agreed to this request. Since the studies have now been completed, it is appropriate at this time to reconsider the question of setting salinity standards for the Colorado River.

Our second recommendation continues with the following sentence:

This recommendation further states that such criteria should be consistent with the above salinity policy and should assure the objective of keeping the maximum mean monthly salinity concentration at Imperial Dam below 1,000 mg/l.

We recognize that the level of 1,000 mg/l has already been exceeded on occasion and under present modified conditions of development and water use this level would be expected to be exceeded again about 10 percent of the time. It should be noted that this concentration is a maximum monthly value and is not, in our opinion, directly comparable to the annual long-term average values which have been cited from time to time in the report. Achievement of this level, therefore, would represent a degree of enhancement of water quality under present conditions.

Because of the complexity involved in setting salinity standards, it is quite probable that the common approach to development of standards will have to be varied. One possible approach, for example, would be to obtain continuous records of flow and salinity at key stations throughout the basin. These records could be analyzed periodically to assure that the central objective of the salinity policy were met. In other words, what we are suggesting with this kind of a recommendation is a nondegradation policy be applied to the Colorado River as the standard.

Recommendation No. 2 concludes with the statement that criteria should be adopted by January 1, 1973. It is recognized that less than 1 year may not be a realistic time period to accomplish this analysis and that a somewhat longer time period may be required.

Recommendation No. 3, as found in the report, is that implementation of the recommended policy and criteria be accomplished by carrying out a basinwide salinity control program concurrently with planned future development of the basin's water resources.

This recommendation is intended to permit continued development of the basin's water resources. However, this development must be accompanied by a comparable degree of salinity control in order to maintain concentrations at or below their present levels if the first policy recommendation is to be adopted.

That concludes our formal presentation, Mr. Chairman. At this time we would stand ready for questions and we also would note that we would be prepared to offer specific recommendations to the conferees if requested.

MR. STEIN: Before we throw this open for questions, I just have one clarifying thing. I think you should ask questions on the whole EPA report, not just these conclusions.

Essentially the only real difference I find between you and Commissioner Armstrong's recommendation is the length of time it would take to do this. You have by January 1973 and he had in 3 years, which would make it February 1975, right?

MR. FREEMAN: That is right.

MR. STEIN: February 1975. Other than that, to get back to the essential points, and you heard Commissioner Armstrong, your recommendations and his are eye to eye as far as you can see?

MR. FREEMAN: Yes, sir.

MR. STEIN: Is that correct?

MR. FREEMAN: That is right.

MR. STEIN: All right.

Are there any questions?

MR. MALETIC: Mr. Stein, may I make a clarification on that?

MR. STEIN: Would you identify yourself.

MR. MALETIC: I am John Maletic, Bureau of Reclamation.

Commissioner Armstrong's statement reads that in 3 years the task force will make recommendations to this conference, and the conference then could decide how to proceed from there.

MR. STEIN: Yes.

MR. MALETIC: That was not a direct statement that in 3 years standards shall be set, and this should be understood.

MR. STEIN: All right. I think that is a fair statement. I think I was speaking of the essence. In 3 years I would suggest that the States, as Commissioner Armstrong says, should evaluate these with them. And if you and EPA made the recommendation to the conference--and I am just putting the two outside dates that Mr. Freeman put, 1973 and February 15 and 16, 1975, anywhere there or between those dates--if you read those recommendations to the conference, I don't like to make predictions, but I bet it wouldn't take the conference very long to back that.

Are there any others?

Mr. Thatcher.

MR. THATCHER: I assume that it will be appropriate for us to react to this when we make our formal statements--

MR. STEIN: Yes.

MR. THATCHER: --which will have a bearing on these things.

MR. STEIN: Yes.

MR. THATCHER: And passing this now doesn't necessarily mean acquiescence to all these.

I have one specific question, because Russ didn't follow the exact wording of the summary report. He mentioned 925 ppm at Imperial Dam in this Point 1. That is different than in my copy.

MR. STEIN: Yes, that should be clarified. Do you want to do that, Russ?

MR. FREEMAN: Yes, sir, we did change the number in the report in view of the updated information presented by Mr. Blackman in his presentation that has been made available and provided since the report was drafted. It did have a higher value indicated.

MR. THATCHER: So your statement is a correction to the summary report?

MR. FREEMAN: Is a correction to the summary report.

MR. STEIN: Let me state this as I understand it. The 865 ppm at Imperial Dam is a 28-year average. The 925 figure is the 1970 average.

MR. FREEMAN: That is the highest annual average that has been observed on the river.

MR. STEIN: Right.

MR. THATCHER: Then there are two different numbers, then?

MR. STEIN: Right.

MR. THATCHER: We need to identify them, then. They are both correct, in other words?

MR. FREEMAN: That is right. But in terms of the wording of the sentence in which that number appears, the 927 is the correct word.

MR. THATCHER: O. K.

MR. STEIN: Nine hundred twenty-seven or nine hundred twenty-five?

MR. FREEMAN: I am sorry, it is 927.

MR. STEIN: All right.

MR. THATCHER: Nine hundred twenty-seven is the 1970 annual average.

MR. DIBBLE: It keeps going up, you see.

MR. FREEMAN: No, sir.

MR. STEIN: It keeps going up and up.

MR. WRIGHT: We are losing ground.

MR. DIBBLE: In just 2 minutes it went up 2 points.

(Laughter.)

MR. FREEMAN: In response to your question, Mr.

Thatcher, that is the highest annual average salinity concentration from the trace of record.

MR. STEIN: Are there any further questions?

MR. TABOR: Question.

MR. STEIN: Yes.

MR. TABOR: The contribution of salinity by irrigation to the Colorado River, is the contribution considered as net or gross? In other words, that which is contributed to the river by irrigation, is that each project taking the salinity of water that goes in, subtract it from the salinity that goes out and that is the contribution?

MR. FREEMAN: No, sir, it is the gross contribution. The concentration of the effluent multiplied by the volume of effluent.

MR. TABOR: It is an increment, isn't it?

MR. FREEMAN: As I understand, the values in the report are in fact determined by measuring the quantity of return flow, the quality of return flow, and calculating loads on that basis.

Mr. Blackman actually made those calculations.

MR. BLACKMAN: The values reported are net values. We determined the salt load entering an irrigated area and the salt load leaving the irrigated area, so it is a net value.

MR. TABOR: Thank you.

MR. DIBBLE: It is an increment.

MR. BLACKMAN: That is correct.

MR. STEIN: Are there any others?

Yes.

MR. DIBBLE: Mr. Chairman, I also have a question of Mr. Russell. In his recommendation which is shown as Recommendation 10 in the report, summary report, on page 7, he says:

> A basinwide salt load reduction program appears to be the most feasible of the three salinity control alternatives.

And I have no problem with that sentence. The next sentence says:

> The scope of such a program will depend upon the desired salinity objectives.

And I think that is true.

But then over in the next page where he gets into his recommendations, he proposes that the criteria should be set and should assure the objective of keeping the concentration at Imperial Dam below 1,000 ppm.

And so I would interpret that to mean that you really are establishing the scope of the program indirectly if that last statement is true. Is that your intent?

MR. FREEMAN: Basically the problem we came to is the same problem that has been discussed several times. What we recommended is a policy of maintaining existing quality as the guiding policy. But in searching for a number in the staff discussions, 1,000 seemed to be a number that could be used if it were properly described and interpreted as to what that 1,000 is. It is a value that essentially represents the upper limit of concentration most of the time with an understanding that on occasion it will be exceeded and the standards would, therefore, have to be written accordingly.

MR. DIBBLE: Well, it would seem to me that the salt load reduction program is something that we don't truly have a handle on yet as to the magnitude of the program, what the costs will be, and that until we know that we shouldn't be setting our objectives because we don't know whether we can-- well, we don't know whether the program is being described in a big enough form or not. If it turns out that it would take an even larger program to meet this objective, then we have to change the scope of the program.

It seems to me that Mr. Armstrong in effect is saying there is still more information we need before we can say how big a program or what size program is feasible.

MR. FREEMAN: Yes. I think what we are having here is sort of a difference in philosophy of how you approach a problem like this, and the philosophy that we used was to establish a goal and hopefully then generate a program to meet that goal or at least try that until such time as it could be shown that the goal was not realistic. The other way around, of course, is to try and do as much as you can and see where you get with that approach.

Oftentimes we feel by taking the approach of establishing a goal and striving for that, that sometimes this adds a little more emphasis to the process. Or turning it around, it allows the people who are doing this, which will be the conferees here, I presume, an opportunity to sort of establish a level of priority for this program and its recommendations.

In other words, if you establish the goal, then I think you are telling us as technicians how hard we have to work. On the other hand, if you allow us to tell you what we can do, you see, we may not want to work too hard.

MR. DIBBLE: Well, I think that we all are going to find we have got to work our hardest, no matter what, and I think you set your goal in your first recommendation. You said that:

> A salinity policy be adopted for the Colorado River System that would have as its objective the maintenance

> of salinity concentrations at or below levels
> presently found in the lower main stem.

Now, that is the objective you are setting for all of this or you are proposing.

MR. FREEMAN: This is the basic recommendation that I feel is the strength of the position, yes.

MR. DIBBLE: So the next point you make when you start to define a figure, you really are beginning to qualify that upper figure. Now, maybe this 1,000, maybe it is not good enough. I am not prepared to say at this time.

MR. FREEMAN: That is right. Well, essentially what we are attempting to do is find a specific number to quantify this objective, and it may be worthwhile to discuss that.

MR. STEIN: By the way, Mr. Dibble, I think you have raised an essential point. Maybe the representatives of the Bureau of Reclamation considered this. Mr. Armstrong also said:

> Historical records at Imperial Dam
> show that the average salinity concentration
> for January 1957 was 1,000.

Now, he seemed to be basing his program on 1,000 or below. I think if we can approach this philosophically, not approaching 1,000 as a number, but just to put something down, the issue here is to say that you are not going to increase the salinity that is at the dam now. And I am not giving you a point of view; I am trying to report it the way I understand it. The issue is that they are trying to say, we want to at least keep the lid on what we have now. The lid is, if we look at the number, in the 900's, if we round it off, if we put this numerically, we will be going somewhere below 1,000. That doesn't mean that at some times you are not going to bounce above 1,000 or we may have that.

But I don't think either Mr. Freeman or Mr. Armstrong put the 1,000 forward as a regulatory figure which was an absolute, but they put the 1,000 forward as the kind of top range that they believed the average represented at the present time. Now, with that, possibly we can approach this.

Do you understand?

MR. DIBBLE: Well, I am certainly listening with great interest. (Laughter.)

MR. STEIN: No, no, here! The objective of the program, as I understand--again just reported by Mr. Freeman and Mr. Armstrong--is to not permit the salinity as measured at Imperial Dam to go above what it generally is now.

Also if you are going to look at it as it goes now to the highest figures, it is in the relatively high 900's. Therefore, as a method of showing this, if you say 1,000 mg/l or ppm at Imperial Dam would be what you are hitting for to maintain it at the present level, this does not mean, at least to me, that 1,000 will be an absolute regulatory figure. I think Mr. Freeman just stated that. You may be able to go above it or have to stay below it at a particular time. But in order to get down to a descriptive term as to what we are putting out on the average--and I understand he is giving us average figures here--the 1,000 is about the average of what is going out in salinity from Imperial Dam now.

MR. DIBBLE: Well, I understand, Mr. Stein, the point you are making, and let me respond in this way. Maintaining salinity at or below levels presently found I think is different than setting a figure, for this reason. And maybe this isn't a very good comparison, but it is the first one I was able to think of just here quickly.

When the State sets a speed limit on the highway at 70 miles an hour, really what they want you to do is travel at or below 70 miles an hour, but there are an awful lot of people that decide that that is the limit at which they should travel all the time. In fact, they maybe even think 5 miles more won't hurt any, so you find everybody driving at 75 when in reality what was intended was that everybody would be below 70.

Now, maybe that is not a good comparison.

MR. STEIN: No, I think your comparison is great, because this is the problem precisely we are grappling with.

MR. DIBBLE: If we want the objective to be to hold the salinity concentrations at or below the level presently found, once somebody starts using a fixed figure they start talking about revolving around that point, as you described. You said, sure, in fact part of the time they will sneak above that a little.

And I think we have to decide which it is we want. Do we want it at or below or do we want it revolving around a stated figure? I think if we all believe in antidegradation we want it at or below.

MR. STEIN: Right. We are going to have this problem with every permit we set, and we are grappling with it now. I commend you to Mr. Freeman's first statement. I am not talking about the figure. The report said 865, maybe it should be 827. He says about 925. But I think the key word there, as I see it, is "about."

Now, obviously when we talk in terms of "about," when we talk in terms of 1,000, we are talking in terms of an average. Whether we mean that 1,000 — and this is the job I think we have to do, Mr. Dibble — to be an absolute limit above which you can't go, or whether we mean it as an average from which we are going to give a certain variance is what we have to decide.

But I think it serves a useful purpose if we round it off at about 1,000 if that is the area, at least the ball park, you are talking in. I am not talking in terms of that for regulatory figures because I think Mr. Armstrong indicated, and I think very properly, that we have to get some pretty refined stuff before we are going to come out with numbers that we are going to use for regulatory figures. But it also seems to me that if we get Mr. Freeman from EPA and Mr. Armstrong from the Bureau of Reclamation both talking in terms of about 1,000, then we know the area we are talking about. And we are talking about a 75- or a 70-mile speed limit and not a 25-mile speed limit, and that makes a tremendous amount of difference.

But I think both of these gentlemen are putting these figures forward, as I understand it, in the same sense.

MR. MALETIC: Mr. Stein.

MR. O'CONNELL: Let me respond to that just briefly.

MR. MALETIC: May I respond? I would like a clarification on that statement on your interpretations of Mr. Armstrong's statement.

There was no statement that he made that addressed itself to 1,000 mg/l mean monthly as a potential standard in the river, and our comments dealing with that were comments pertaining to the recommendations of EPA only and, therefore, did not reflect an Interior Department position.

MR. STEIN: I hope I said that, and I hope I won't have to read it. But I am quoting from Mr. Armstrong, I think, and he said:

> Historical records at Imperial Dam show that the average salinity concentration for January 1957, whatever, was 1,000 mg/l and for December 1967 it was 992 mg/l.

Then he goes on to say:

> If a numerical standard of 1,000 mg/l maximum monthly average is established, it will probably be necessary...' etc.

I think Mr. Armstrong made himself very clear that he couldn't come out with any numerical standard at all--

MR. MALETIC: Now you have got it.

MR. STEIN: --but again in reading these numbers and in reading Mr. Freeman's numbers--and this is what I think I said to Mr. Dibble--it is very important for the conferees to know that when we speak of a speed zone, we are speaking in the terms of 70 miles an hour instead of 25 miles an hour. This is just the significance of the figures.

I think we understood Mr. Armstrong's position very clearly that this was too early a stage to set any numerical figure. However, the way I read his statement, and after listening to Mr. Freeman, I believe from the historical record they are not speaking about anything very much different. They are both thinking of the same thing as to what the existing situation is, the possible philosophic possibility of not letting it go above that, and keeping that as a summa.

Yes.

MR. O'CONNELL: I would like to make one comment along those lines.

I believe the first and second recommendations are completely consistent, paraphrasing what Commissioner Armstrong said on page 4, with present levels of development, a maximum monthly average value at Imperial of 1,000 could be expected to be exceeded about 10 to 12 percent of the time, something like that.

In our first recommendation the statement was made salinity should be maintained at or below existing levels. The second statement says how far below existing levels we think we ought to shoot for, which is the 1,000 at Imperial Dam. In other words, under present conditions you could expect it to be exceeded 10 percent of the time. We are saying that should drop to zero. So it is how far below.

MR. STEIN: Let me say, we don't intend to go much after 5 o'clock.

All right.

MR. WRIGHT: Mr. Stein.

MR. STEIN: Yes.

MR. WRIGHT: Could I ask Mr. Freeman, you mentioned 927 mg/l was the high annual for the period of record. Would you tell me what year that occurred?

MR. FREEMAN: Do you have those records?

...Slide...

MR. BLACKMAN: The figure quoted was 927 mg/l as the annual average for 1970.

MR. WRIGHT: 1970?

MR. BLACKMAN: Right.

MR. WRIGHT: And that is the highest for the period of record, is that right?

MR. BLACKMAN: No, there have been higher momentary values--

MR. WRIGHT: No, highest average annual.

MR. BLACKMAN: That is correct.

MR. STEIN: Are there any further questions?

You know, I am glad you brought that chart out. Please leave it here. I would like to--

MR. WRIGHT: Mr. Stein, I hadn't yielded the floor yet, if you don't mind.

MR. STEIN: Go on. I don't mind a bit.

MR. WRIGHT: Fine.

Mr. O'Connell, you mentioned that you thought Recommendation 2 was a paraphrase of No. 1. I would suggest that there is a significant difference between a salinity policy and a specific quality standard.

MR. O'CONNELL: No, I just said they were consistent, that is all.

MR. STEIN: Do you want to push that chart over a little to the right so we get the dates? You know, this is the most significant chart to me, and I didn't see it before today, but I just ask you to look at this. This conference has been in business since 1960. They have got the figures since 1960 and 1970. We have done a pretty good job on radiation. Look what has happened with salinity in the 10 years we have been in existence. I think if these figures are right they just speak for themselves.

MR. WRIGHT: Mr. Stein.

MR. STEIN: Yes.

MR. WRIGHT: Mr. Freeman, when you were discussing Item 2, Recommendation 2, I believe that I heard you, and your recorder might come back, that a longer time than by January 1, 1973, might not be unreasonable.

If you will recall, on November 15, 1967, the conferees met when we were writing the water quality standards for other parameters and adopted a resolution requesting the salinity report. It has been 51 months that EPA has been working on the report. I actually received a copy in December, so that is about 47 months--49 months it took to write Appendix A, B and C and the summary report. We are advised it is another 30 days before the Bureau's printed report can come to us.

Realizing that, let's say, it has been 50 months since we were thinking about it last and the ball was in the field of the Federal Government, would you care to expand on what you mean by a little more time than by January 1973?

MR. FREEMAN: I think you have hit precisely upon the problem, and that is this recommendation was written as the report was written, and the report has been sometime in the printing and review process. Therefore, it might be appropriate to consider that some of the time that has elapsed since this date was selected be considered. I believe the recommendation at the time this was written down we were considering something in the 18 to 24 months, although you might check with Mr. O'Connell, because he was the one who last had it.

MR. STEIN: Mr. O'Connell?

MR. O'CONNELL: That is pretty close, yes.

MR. STEIN: In other words, if you are considering 18 to 24 and the Bureau of Reclamation is considering 36, we are narrowing the gap. (Laughter.)

All right, any other questions or comments?

MR. WRIGHT: Thank you very much.

MR. STEIN: Are there any other comments or questions on the Federal report?

MR. TABOR: I assume this table that is on the screen is in one of these appendices? (See 922a.)

MR. STEIN: Yes, it is.

And again I ask you to look at this very, very carefully, because this is what struck me. We have been with this conference since 1960 to 1970. We were supposed to reduce the salinity. And as has been indicated on the table, the salinity has risen significantly in the past decade.

Now, the question is what do we do. Do we just roll on, do we put some brakes on, or do we let the next decade take care of itself the same way the last one did? Unless someone would show us that these figures are wrong, I think they speak for themselves.

FROM THE AUDIENCE: May I ask again, was that table in the report?

MR. FREEMAN: No, sir, it is not in the appendix report. We will have a copy made available.

MR. DIBBLE: Could you for tomorrow?

MR. FREEMAN: Yes.

MR. STEIN: Are there any further questions or comments?

MR. WILLIAMSON: I might pass a comment on that No. 2 recommendation there of setting specific standards. This gets down-- I know the Federal push is get a standard, period. We went through this in 1965, get a standard.

When you are on the other end of setting the standard, we have to enforce it, and this puts us in a position when we write a standard who do we work on, how do we do it. In other words, what can I do if the salinity goes up? I have got to be able to go back and say, "Cut it out." And as yet we don't have those answers.

This is the other part of the study, is to try to prove that we can through some major projects reduce the salinities. So we are at that point. To establish a numerical standard is only asking for one awful lot of headaches, because as soon as it is violated somebody is going to come up and say, "Enforce it" and then what do I do? And looking at pending Federal legislation, maybe they would even bring suit against the Administrator for not enforcing the standards when it is violated.

So these are some of the other sides of setting this standard. I certainly go along with a nondegradation policy. We all have this. We have all got the agreement in seven States that we do everything on a point source if we can. But any time we write a number down, I don't care whether it is as a policy number or as a standard, somebody is going to come up and say, "That is the standard; you enforce it," and we don't have the answers. I don't think we for sure have them yet.

We have a good program here laid out that might be the answer, but I think we have got to wait and see if it is.

MR. STEIN: Any other comments or questions on the Federal report?

If not, thank you very much, Mr. Freeman.

MR. WRIGHT: I have one more question.

Mr. Freeman, could you give me the source of your data for that last table, in particular the 927?

MR. BLACKMAN: Most of these data are from the U. S. Geological Survey and water supply papers. I would have to check that specific figure.

I have just been told that that 1970 figure represents a partial water year. However, the previous year, 1969, average was 920 and that was for a complete water year.

MR. WRIGHT: Thank you.

MR. STEIN: Are there any other questions or comments on this?

If not, thank you, Mr. Freeman.

Now, I think we have enough time. We are going to call on Mr. Thatcher and Mr. Wright, and we are going to revert back to our tailings pile problem and try to complete that tonight.

Mr. Thatcher.

LYNN M. THATCHER
DEPUTY DIRECTOR OF HEALTH
UTAH STATE DIVISION OF HEALTH
SALT LAKE CITY, UTAH

MR. THATCHER: Mr. Chairman, the draft of regulations that were similar to the ones that EPA recently submitted to us for review were prepared by Utah a few years ago, but they haven't yet been officially adopted and this is primarily due to lack of program funding at the State level. I am pleased to report at this time that this was partially rectified by the 1972 budget session of the Utah Legislature which adjourned last week.

The State of Utah took a positive stand against removal of tailings. This related particularly to the tailings pile in the Salt Lake Valley early in the development of this problem, I don't remember the exact year, but while the pile was still active. And we learned inadvertently that this was being done; we hadn't known about it. As soon as we found this out, we prohibited all hauling from the pile and to our knowledge this edict has remained in effect. We are now attempting to identify the areas of deposit accomplished for this period of control and we believe that these are rather minimal.

We had a few recommendations on the draft of the regulations that EPA submitted for our review. We gave these verbally to representatives of the Denver Office of EPA.

In the interest of saving time, I won't delineate these unless you specifically want me to, and I can say that we do agree with the regulations in principle, and it is our intent now to move ahead and adopt them officially in the State of Utah.

MR. STEIN: I understand most of your recommendations have been incorporated in the latest draft.

MR. THATCHER: I see. I haven't seen the latest draft.

MR. STEIN: Are there any comments or questions?

Mr. Wright?

MR. WRIGHT: Thank you very much, Mr. Stein.

I had an inquiry about the discharge from tailings piles in the Durango area, and an environmentalist, quote, in New Mexico said he heard that the problem was significant again. I attempted to obtain STORET retrievals, etc., and found the data for the past couple of years was difficult to track down, apparently due to reorganization within EPA, shifts in responsibilities of the laboratories, and delays in putting the data into STORET and not knowing who to send the data to. I would appreciate it if EPA could attempt to get the house in order just a little bit better so that we can obtain data when we are sharing it.

The State of New Mexico has reviewed the regulation and finds thatit will not be suitable on a Statewide basis. The recommendation is suitable as far as it goes, but it only deals with one aspect of the problem and that is the mill tailings. New Mexico is presently drafting a regulation and expects to adopt it within a year and the regulation will address itself to the whole problem of mine dumps, quarries as well as tailings.

Mr. Kaufman of our Radiological Health Unit feels that some low grade ore dumps are much more of a hazard than the mill tailings themselves. At the present time I can report that the only mill in the Colorado Basin in New Mexico is now inactive, the pile has been covered at this time and is dry, in a desert area where the rainfall is approximately 7 inches a year.

Thank you.

MR. STEIN: Mr. Rozich.

MR. ROZICH: Yes. The information that radioactivity is emitting from Colorado in the vicinity of Durango is news to me. Of course, Mr. Jacoe, I don't see him in the audience, whether he can address himself to that. But I thought we solved the problem by moving the mill to Farmington, New Mexico. (Laughter.)

MR. STEIN: Are there any further questions?

I don't want to pursue this, but let me indicate that if you have any problems on data, call on us. I have worked with these people in Colorado for years, and we may have had other problems, but getting data or the information wasn't one of them. This I don't quite understand. If we have a problem, it will only take a phone call.

I would suggest again, before we recess for the night, I don't think that we are too far apart on those uranium tailings controls. I suspect that New Mexico doesn't have much of a problem--they have one mill which pretty well is taken care of--and that several of the other States don't have significant problems. Possibly the States that have the problems here are maybe Utah and Colorado. I think Wyoming was fortunate enough in that the uranium mills developed there a little later than in the other States. Art Williamson was alert enough to look at his sister States and figure that the best place for a uranium mill wasn't at the side of a stream but over on the mesa where it was dry and site location was probably the best way of preventing the problem.

But in dealing with the Colorado experience and what we have heard from Utah and the Federal people, I think we have a relatively minor variation on the same requirement and something which has been tested certainly at least in one State. Therefore, we should be very near to a conclusion on that, and I hope we can wrap up the tailings problem.

On the salinity problem, of course, we have many more presentations to make. We have to hear from the States on this, but I am very much encouraged, because I think essentially the reports that we have from EPA and the Department of the Interior are very compatible.

MR. THATCHER: Mr. Chairman.

MR. STEIN: Yes.

MR. THATCHER: Excuse me. Just following along your comment there, perhaps we should point out that the one aspect of the radium tailings that would become an interstate problem is leaching of uranium, or I assume that this is the case, or leaching and draining. We did achieve significant gains in this area before and now each State, of course, has the local problem of wind erosion.

MR. STEIN: I think this is the question. Of course, Mr. Thatcher, you weren't here this morning. I think we indicated that one of our successes and the States'--because you are the people who did it, both the industry and the States--has been the control of this problem. And again I say when you deal with the two States--Utah and Colorado--that had the problem, they had to do the major cleanup. You have done the cleanup. I think we made that very, very clear in the record.

The only question we have now is the residual aggravation on which we said at the last conference we were going to come up with a suggested regulation for tailings. This we have done. I suggest that the conferees agree with this, get together on this and go on. I don't see really any material difference on this. As far as the direct Federal involvement is concerned, one of the areas where we can point to success in abating the pollution, if we complete this task, is that we have turned it back to the States. I hope we can get that done at this conference.

However, the major point that you have to consider is where we go on the salinity control. Now, on the salinity control, EPA and the Interior Department, as far as I listened to the report, are essentially moving down the same road in tandem. I don't see any differences except differences in detail. I think again the record speaks for itself. But the only reason I emphasize that is that I don't think you could have said that in past years. At the present time they are working very closely together.

I would ask the States to present that, because again I think this is one of the problems that we can put on the road and sit back and really come up with an achievement. Essentially I don't think we are too far apart, at least the Federal agencies are not too far apart, and I hope the States can get together and arrive at an accommodation.

Again let me say just for myself that some places I ask questions and some places I don't. The reason I asked Commissioner Armstrong so many questions was that I think his statement was a tremendous breakthrough. His document, as well as the EPA recommendations, is something that should be very, very carefully considered by the State conferees. It certainly gives us a blueprint as to how we can move forward on this problem.

MR. THATCHER: I am sure the States could do this.

Let me get back to one more question on the tailings. This may have been answered this morning.

At the sixth session something was said about the Federal Agency that then was handling this problem cooperating with the Atomic Energy Commission in developing some long-range controls which the States felt pretty powerless to cope with. Did anything come out on that this morning?

MR. DICKSTEIN: I believe that Mr. Malaro from AEC in his statement addressed this area, and it seems we are coming along.

MR. THATCHER: Thank you.

MR. STEIN: You know, we are coming along faster on the long-range problem than treating the salinity. (Laughter.)

What is the half-life of that stuff?

MR. DICKSTEIN: Sixteen twenty.

MR. STEIN: Sixteen twenty. You know, there are probably only two guys in this room, Carl Eardley and I, who know what 1620 means. That is what they used to pay a clerk back in the old days of the Government. (Laughter.) But that is a long time in years, and when you talk about a long-range program, it is going to be longer. (Laughter.)

All right. Are there any other comments or questions?

MR. WESTERGARD: I have a question. As one of the conferees, and I am sure some of the people here, I would be interested in knowing what the schedule is going to be tomorrow, what the anticipated time elements are. You did take registrations for statements, and that might give some indication of the time.

MR. STEIN: I think that is a very good question. You know, this is always a problem, knowing how long people are going to speak. I recognize that when people come here who are not professionals, while their estimates are given in the best of faith, they generally are under.

We deal with some pros, you know, who know how they are going to speak. You know, one Washington Congressman went to the Mayflower Hotel on the wrong night. While he was roaming around the halls, suddenly he saw a room with a function going on, and the speaker hadn't shown up. So they asked him in and he spoke. Then the press heard about this, and they thought it was a fascinating story.

They said, "Mr. Congressman, what did you speak about?"

He said, "Oh, about a half an hour." (Laughter.)

But here is what we have. Here are the people who are going to have to speak on the list.

Sheldon Boone, Soil Conservation Service, United States Department of Agriculture; a communication from the United States Army Corps of Engineers; Sacramento--

Maybe when I call the names, you can call out.

Mr. Boone, how long do you expect to speak?

MR. BOONE: Not too long, 10 minutes.

MR. STEIN: All right. (Laughter.)

You know, that is my case right there.

M. Holburt, Colorado River Board of California; D. Kennedy, Metropolitan Water District; L. Weeks, Coachella Valley County Water District; R. Carter, Imperial Irrigation District; L. Morrill, Colorado Water Conservation Board; R. Fischer, Colorado River Water Conservation District; D. Paff, Colorado River Commission of Nevada; D. Hale, New Mexico Interstate Stream Commission; Gaylord Skogerboe, Colorado State University; a communication from National Council of Public Land Users; Charles Wilkinson, Native American Rights Fund; Dr. H. K. Qashu, University of Arizona; Dr. G. William Fiero, Jr., Sierra Club; G. Bryant, Fort Yuma Indian Reservation, Winterhaven California; F. Brown, Quechan Tribal Council, Yuma, Arizona; Lorne G. Everett, University of Arizona, Department of Hydrology, Tucson; and Mary Kozlowski, Nevada Open Spaces Council.

By the way, in preparation for this I was down around Yuma and Winterhaven a while ago and I know you were trying to get some Federal officials to visit the reservation down there. I don't know if they showed, but I guess you have come here and you are welcome.

We will recess now, but let me indicate that I understand that the expanded recommendations read by Mr. Freeman will be available in a few minutes for the conferees, and it is suggested that you might want to get those before you leave this evening.

With that we will--

FROM THE AUDIENCE: Mr. Stein, what time are you going to start in the morning?

MR. STEIN: I will announce that in a moment.

We are going to reconvene in the same place at 9:30 tomorrow morning, and 9:30 it is. We are going to start right on time.

We stand recessed until tomorrow.

- - -

(Whereupon, at 5:15 o'clock an adjournment was taken until 9:30 o'clock, Wednesday, February 16, 1[illegible].)

MORNING SESSION

WEDNESDAY, FEBRUARY 16, 1972

9:30 o'clock

MR. STEIN: Let's reconvene.

Starting this morning we will clear up some of the points that were raised yesterday.

Mr. Blackman, I believe you wanted to make a comment on the chart entitled Average Annual Total Dissolved Solids Concentrations in Selected Stages.

MR. BLACKMAN: Can somebody get the lights, please.

...Slide... (See 922a)

The question as to the source of the 1970 TDS figure at Imperial Dam was raised yesterday. This figure was derived--well, let me say that on this side of the chart I have penciled in the monthly flow weighted mean TDS concentrations for 1970. You will see that the figure 960 for February was circled. We retrieved this data from STORET and that particular figure was missing. We correlated the February value from previous years' data. Using that one correlated month, the 927 figure was derived.

Now, I have further listed on this side (indicating) of the chart the 1971 monthly flow weighted mean TDS concentrations, again USGS data, which are presently available in STORET for your information.

AVERAGE ANNUAL TOTAL DISSOLVED SOLIDS CONCENTRATIONS*
AT SELECTED STATIONS
(1960-1970)

YEAR	CAMEO COLO.	GREEN RIVER WYO.	LEES FERRY ARIZ.	GRAND CANYON ARIZ.	HOOVER DAM ARIZ.-NEV.	PARKER DAM ARIZ.-CAL.	IMPERIAL DAM ARIZ.-CAL.	NORTHERLY INTERN BOUNDARY
1960	429	347	593	629	671	631	777	——
1961	469	319	710	784	697	669	820	——
1962	338	276	525	536	685	699	818	——
1963	582	302	934	1,030	677	681	791	——
1964	498	296	811	913	722	679	624	1381
1965	369	322	572	636	809	765	916	1382
1966	519	382	517	566	743	755	896	1330
1967	468	287	621	681	675	689	842	1322
1968	439	363	647	691	699	692	846	1307
1969	436	315	602	667	776	748	926	1298
1970	388	389	631	718	776	784	927	1264

*ALL VALUES IN MILLIGRAMS PER LITER.

MR. STEIN: Does that complete the chart?

May we have the lights, please?

We will begin calling on other people who wish to make statements now. Are there any questions or comments you want to raise at this time on the EPA presentation or the presentation of Commissioner Armstrong?

If not, we will go on to the other presentations.

Sheldon G. Boone, Soil Conservation Service, United States Department of Agriculture.

SHELDON G. BOONE
SOIL CONSERVATION SERVICE
U. S. DEPARTMENT OF AGRICULTURE
DENVER, COLORADO

MR. BOONE: My name is Sheldon G. Boone.

Mr. Chairman and other Federal and State conferees, I have been asked by the Office of the Secretary of Agriculture to present this statement at this conference.

We are pleased to have this opportunity to present a statement concerning the mineral water quality problem in the Colorado River relating to the Environmental Protection Agency report entitled "The Mineral Quality Problem in the Colorado River Basin." The Department of Agriculture has both technical and administrative interests and responsibilities within the basin.

We note that the report shows that while 65.6 percent of the total salt load at Hoover Dam comes from natural sources, 33 percent comes from irrigated agriculture, accounting for nearly all of the manmade salt load to the river. In terms of salt concentration, however, irrigation contributes 37 percent. Increased salt concentration due to irrigation comes about in two ways: (1) As a result of consumptive use of water which diminishes stream flow, and (2) as a result of increased salt loading to the stream through the leaching of salt from the soil profile and underlying aquifers. These are natural results of the irrigation process and ones which can be modified only in degree by system improvement and improved water management practices.

A major portion of the high water producing lands in the basin support a forest type of vegetative cover. These lands are major contributors to economic and social well-being of the Colorado drainage in terms of timber, forage, wildlife habitat, recreation, and the dependent industries they support. They also contribute a major source of runoff water for the region. The management of forest land for commodity production, water production and water requirements under the multiple-use concept and related problems such as water quality, soil erosion, and sediment production make these areas a highly significant part of the salinity control planning effort.

The Department's watershed management program could make a significant contribution to salinity control programs directed toward reduction of natural salts associated with sediment production from public land. A function of this program is to provide scientific soil, geology, and hydrology inputs for resource planning and development programs. These inputs are necessary to provide a firm basis for long-range planning and to assure that projects are designed and conducted in a manner which protect environmental values. Other major functions of the program are:

1. To develop the protection requirements needed to assure that development and management activities meet established watershed objectives and standards.

2. To restore the productivity and water handling capabilities of denuded and damaged watershed land.

3. The design and application of resource management practices and supplemental structural measures, where appropriate, to improve water quality and quantity or timing of water yield.

4. To optimize the public benefits from the available water resources of National Forests through coordination

of Forest Service resource use and development activities with multiple purpose water resources development.

5. Monitoring the effects of resource management uses on the overall quality of the soil, water, and air resources.

The installation of improved irrigation water delivery systems and the use of on-farm application systems and water conservation practices can make measurable contribution to improved water quality in the Colorado River Basin. The improved systems would reduce the amount of water consumed per unit of crop output and decrease the water depleted by non-economic vegetation, thereby minimizing reduction in stream flow. Improved water management by the irrigators and the installation of adequate drainage systems will reduce deep percolation and the volume of groundwater flow through saline formations, thereby reducing salt loading.

Implementing present technology for improving irrigation water management will give a needed reduction in salt loading and salt concentration. These practices which make a marked contribution to water quality improvement also result in increased crop production and a higher return to the farm enterprise.

Although programs are available to assist landowners and local organizations in improving irrigation systems and water management, a high degree of success depends upon a number of factors. These include (1) an adequate educational program; (2) increased technical assistance available to landowners; (3) cost-sharing or loan assistance where high capital investment is required; (4) major system improvements through group action; (5) phasing out irrigation on soils with natural high salt content; (6) selection of new areas for irrigation which have soils and underlying formation with low salt content.

There is a need for continued study and research on improved soil and water management practices in both irrigated and nonirrigated areas in relation to salinity control. The major area of study should be on minimizing saline levels in return flows.

The reduction of erosion in areas where surface soils are high in salt will reduce sediment and salt loading from natural diffuse sources. Identification and characterization of these diffuse areas will permit development of management practices to minimize salt losses. Additional research on the impacts of improved watershed management on salt loading is needed.

From research on the pressing problems of water resources in high elevation forest and alpine areas, two methods of watershed treatment have evolved for increased water yield.

1. Rearrangement or reduction of vegetative mass in the timber harvest zone.

2. Conversion of deep-rooted stands of dense brush on noncommercial timber to shallower rooted stands of grass.

Manipulation of vegetative cover and other water yield improvement techniques can result in increased streamflow without damage to the watershed or to areas downstream if the activity is carefully planned and executed as a part of a coordinated land resource management program. The danger lies in proceeding too fast with too little knowledge of the plant-soil-water and other environmental relationships involved.

Ill-conceived, poorly executed programs are likely to cause considerable damage to watershed, soil and water quality and add to salinity problems. Close coordination between weather modification programs and land treatment programs will be essential to minimize any adverse effects on anticipated increase in precipitation or runoff.

We have made no attempt to evaluate the input data used in the preparation of the report. Lack of time allotted for review and the scope and complexity of the problem made it impossible for us to make such an evaluation.

S. G. Boone

With respect to the report, there is very little material that relates to water pollution control programs except in the area of mineral quality. Although salinity is the most serious water quality problem in the Colorado River Basin, pollution problems of virtually every form may be found in the region. Decisions relating to salinity improvement programs must, therefore, consider impacts on all existing and planned water resource utilization and developments.

The report is weak in considering in depth the effects of some of the proposals. For example, phreatophyte control can have a significant adverse effect on aesthetics, fish and wildlife habitat. Vegetative manipulation to increase streamflow can increase storm associated runoff with increased sediment production and channel instability. In addition, drastic removal of vegetative species could affect site productivity, recreational values, and community economics. An environmental analysis of the effects of each proposal is essential before final decisions can be made.

The Department will continue to cooperate with other Federal, State and local entities to solve the salinity problems encountered in the Colorado River system. Cooperation from all levels of government are necessary before much accomplishment will be realized toward the overall objective of salt load reduction.

Because all aspects of water and related land resource development, control and management are related, it appears that the most feasible solutions to mineral quality control will result in the implementation of comprehensive basinwide plans. Water quality control planning should become a major consideration in agency or interagency river basin planning efforts in the Colorado River Basin. We concur in the adoption of a policy to plan and implement programs to reach the objective of maintaining salinity concentrations in the Colorado River at or below levels presently found in the lower mainstem.

In closing we would like to affirm our willingness to work with all concerned to the limits of our authority and expertise in developing, evaluating and recommending measures and programs for controlling or minimizing water problems in the Colorado River Basin.

Thank you.

MR. STEIN: Thank you, Mr. Boone.

Are there any comments or questions?

MR. WRIGHT: Yes, Murray.

MR. STEIN: Go right ahead.

MR. WRIGHT: John Wright from New Mexico.

Did I hear correctly that you stated that the technique of trickle irrigation will decrease deep percolation in contact with salt-bearing stratas and thereby reduce the salt load?

MR. BOONE: No, sir, we didn't say anything about deep percolation--or about the trickle irrigation.

MR. WRIGHT: Can you tell me the context that that phrase did occur? I remember you saying something about deep percolation or preventing deep percolation and I wondered how you did that.

MR. BOONE: The statement was, I believe, to improve water management by the irrigators, and the installation of adequate drainage systems will reduce deep percolation and the volume of groundwater flow through saline formations thereby reducing salt load, salt loadings.

MR. WRIGHT: In other words, just better drainage systems in some cases will help us?

MR. BOONE: Yes, I think the object would be to expose the water to the least amount of soil profile and underground aquifers. In other words, getting the return flow back to the stream before it has an opportunity to pick up a high salt content.

MR. WRIGHT: Thank you.

MR. DICKSTEIN: Mr.Boone, I would like to briefly ask a few questions on irrigation practices.

I have read quite a bit on irrigation leading into this conference, and several of the articles I have read have indicated that it is a general practice of the irrigator to open up the gate in the morning, go to work and then close the gate at night. Now, if something could be done about this immediately, couldn't we greatly reduce the leaching in our growing practices? It seems to me obviously a plant just takes so much water and the excess water, all that really does is leach, is that true?

MR. BOONE: Well, I think this is a general statement, and we find all ranges of expertise in terms of handling irrigation water. It seems to me that the programs that we have in the Department and that have been available to irrigation farmers have made immeasurable contributions to increased efficiency in water use and will continue to do so, and perhaps additional effort needs to be made along this line.

MR. DICKSTEIN: That more or less goes along with the area discussed of education with the farmers and educating them about the proper use of water.

MR. BOONE: Yes, that is right.

MR. DICKSTEIN: Also you made a comment, it seems to me that technologically we do have many of the solutions right now, it is a matter of implementing them, is this true?

MR. BOONE: This is true in many fields. I believe it is also true in irrigation.

MR. DICKSTEIN: Thank you.

MR. STEIN: Are there any other comments or questions?

If not, thank you very, very much.

I believe we have a communication from the Corps of Engineers.

MR. O'CONNELL: Yes, we have a communication from the District Engineer, Sacramento District Corps of Engineers, which I would like to offer for the record.

MR. STEIN: Without objection, that will be entered in the record as if read.

(The above-mentioned letter follows:)

DEPARTMENT OF THE ARMY
SACRAMENTO DISTRICT, CORPS OF ENGINEERS
650 CAPITOL MALL
SACRAMENTO, CALIFORNIA 95814

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9 February 1972

Regional Administrator, Region IX
Environmental Protection Agency
100 California Street
San Francisco, California 94111

Dear Sir:

Reference is made to your letter of 13 January 1972 inclosing a copy of your report on "The Mineral Quality Problem in the Colorado River Basin" which is to be the basis for the Federal-State Enforcement Conference on the Colorado River to be held 15-17 February in Las Vegas, Nevada.

A study of the flood and related water resource problems of the Colorado River and tributaries above Lee Ferry, Arizona, has recently been reactivated by this District. As a part of this investigation, consideration will be given to possible solutions to water quality problems in the basin. The purpose of the study is to develop solutions, where feasible, to the flood and related water resource problems of the area, both locally and on a basin-wide comprehensive basis. It is anticipated that several years will be required to complete the investigation.

Studies relating to water quality and salt sources in the Upper Colorado River Basin have not been initiated by this office at this time. Therefore, we do not propose to have a representative attend the conference in Las Vegas on 15-17 February 1972. However, because of our recently activated studies on the Upper Colorado Basin, we would appreciate receiving data on water quality problems and any suggested solutions which might be presented at the conference, including any transcript or summary which may be prepared of presentations made at the conference.

Thank you for the opportunity to review your report and the invitation to participate in the conference. We will keep you advised of any proposed improvements affecting water quality or which may include provisions for reducing the salt load of the river system that may be developed during the course of our studies on the Upper Colorado River Basin.

Sincerely yours,

JAMES C. DONOVAN
Colonel, CE
District Engineer

MR. O'CONNELL: Copies have just been distributed to the conferees. Just for the benefit of the audience I will summarize it by saying that the Corps states that a study of flood and related water resource problems of the Colorado River and tributaries above Lees Ferry, Arizona, has recently been reactivated by the District, and they will keep us advised of any proposed improvements affecting water quality or which may include provisions for reducing the salt load to the river system that may be developed during the course of their studies on the Upper Colorado River Basin.

MR. STEIN: At the present time we are going to call on the States, and then we will call on people who have indicated that they wish to speak.

First Arizona.

MR. TABOR: No comment from the conferee.

MR. STEIN: California.

MR. DIBBLE: Mr. Chairman, before I make any comment, if I do, I would like to call on various organizations from the State that have indicated they would like to make a statement.

The first one I would like to introduce is Myron Holburt, who is the Chief Engineer of the Colorado River Board of California.

MYRON B. HOLBURT

CHIEF ENGINEER

COLORADO RIVER BOARD OF CALIFORNIA

LOS ANGELES, CALIFORNIA

MR. HOLBURT: Thank you, Mr. Dibble.

Mr. Chairman, I have a short statement, of which I have some extra copies, enough for the conferees.

My name is Myron Holburt, Chief Engineer, Colorado River Board of California.

The Colorado River Board is the California State agency with the statutory responsibility of protecting the rights and interests of California, its agencies and citizens, to the water and power resources of the Colorado River System. The Board is composed of six members appointed by the Governor of California, one each from each of the major public agencies with water and power rights in the Colorado River. There are the three urban agencies: the Metropolitan Water District of Southern California, the Los Angeles Department of Water and Power, San Diego County Water Authority; and three other cultural agencies: Imperial Irrigation District, Coachella Valley County Water District, and Palo Verde Irrigation District.

I think most of you are aware of the intensive activities of the Colorado River Board in the last few years in attempting to seek solutions to our salinity problems. The Board's basic comments on the draft edition of the report that was submitted to the conferees today are included in the joint statement prepared by the State Water Resources Control Board, the Department of Water Resources and the Colorado River Board, and this was presented by the conferee, the State Water Resources Control Board, in a letter that is included in Appendix D to this report.

Basically we are in agreement with Recommendations 1 and 3 as they are now in the report, and that is that we have as objectives the maintenance of salinity at or below present levels and we achieve this objective by a basinwide salinity control program.

We are opposed to Recommendation No. 2 in the report calling for establishment of specific numerical criteria by January 1973. And basically, the reason we are opposed to it is that we can see very little value in the efforts of the conferees and the Federal Government in trying to establish numerical criteria. If we felt that numerical criteria would help us, we would be for it, because together with Arizona we have the position of getting the impact of all the salinity problems in the United States by being at the lower end of the basin.

I think the basic situation where we stand today is that after much time and effort, all of the basin States and the Department of State together with Interior are united in going forward with a major salinity control program.

And although to date these studies of the salinity control program, which have been largely on a reconnaissance level, have been favorable, we don't think that we should attempt to even start the setting of numerical criteria until we better know the results to the feasibility studies of this salinity control program.

And thirdly, I think that in the absence of salinity control projects, the only way in which numerical criteria could be enforced would be by taking actions against water users in the Upper Colorado River Basin States, and these States have indicated that any attempt to establish enforceable numerical criteria would be viewed as an attempt to threaten their economic development and would be in opposition, at least as they view it, to the Colorado River Compact.

So basically, we believe that instead of working on numerical criteria at this time, we urge that the Environmental Protection Agency take three basic steps:

1. Expedite the ongoing collection and research programs and fund additional programs. Specifically, there is one program that is up for consideration by the Environmental Protection Agency which I feel should be funded immediately,

and that is the program submitted by Professor Skogerboe in the Colorado State University entitled "Irrigation Practices, Return Flow Salinity and Crop Yields." And the basic thrust of this research project is to try and determine the effect of reducing return flow and deep percolation from crops and what the effect is on the salinity of the return flows. There is a lot of speculation on this, but we don't as yet have any good research project to cover this activity, and I believe that EPA could do a real service by acting on this request which is now before it.

Secondly, I believe the EPA should utilize its existing expertise in working with the Bureau of Reclamation. You have people like Russ Freeman, Jim Vincent, Jim Russell, who have been scattered throughout your organization now, but they have gained valuable experience in working on this program, and I feel that they should be utilized in working with the Bureau in some capacity.

And finally, you should continue to transfer funds as necessary to the Bureau, as you have in several other programs which have been going forward today.

I have one other comment and that relates to two recommendations that were in the draft report but deleted in the final report. Unfortunately, these two recommendations are still in Chapter VIII of the report. They relate to, one, setting up a task force to develop numerical criteria, and secondly, consider the possibility of a new agency. I think we are all in agreement that the Bureau of Reclamation shall move forward on this program, but it is very confusing to pick up a report and see that the recommendations are no longer in the front of the report, but the recommendations, together with all the backup, are still contained in Chapter VIII of the report. I believe EPA should take some measure to eliminate this confusion.

Thank you very much.

MR. STEIN: Thank you.

Are there any comments or questions?

I would like to understand what you are saying. And please understand, I just want to get this.

Are you saying that you are in favor of numerical criteria but not now?

MR. HOLBURT: No, I am saying that we should defer any consideration of numerical criteria until we better know the results of these feasibility studies.

MR. STEIN: Do you think we should ever have numerical criteria?

MR. HOLBURT: I don't know. There may be a time when it is valuable, but it certainly isn't now.

MR. STEIN: Right. Then you don't go as far as Commissioner Armstrong when he said, speaking yesterday."This Department,"that is Interior,"accepts the need for numerical standards"?

MR. HOLBURT: No, I don't. I don't think that the Department of the Interior should be spending its effort trying to develop numerical criteria. They have got a big program in terms of getting some physical works and implementation on salinity control. That is where their efforts should be.

MR. STEIN: Here is something we are looking for. We saw the chart that Mr. Blackman addressed himself to this morning. If the figures or the information on which that chart is based is substantially correct, we have a steady increase of salinity in significant places in the Colorado River in the last 10 years. Now, if we are going to prevent that from creeping up, how will we know when to blow the whistle unless we have some kind of benchmark?

And I am not arguing criteria with you. I am just trying to give you the problem that we have here. In other words, we are the Agency -- with California agencies and the agencies in the other States--responsible for the conditions of the waters in the country. If,after a 10-year trend period, you see salinity coming up and we are looking for a device to regulate that to see that it gets better and not worse, how do we do that? How do we approach it?

MR. HOLBURT: Oh, I think--

MR. STEIN: Usually, and I am not saying just in this field, but in any other regulatory field, whether it is cities or industries, we use numerical requirements to see what is done. Now, I am trying to understand what we are driving at or how we do it here without that.

MR. HOLBURT: Well, I think the response is that what we do is we accelerate the salinity control program to see that it is moved ahead as fast as possible. We want to see constructive and every feasible salinity control project we want to see implemented--every potential feasibility control measure. We want the best quality water we can get. We are not concerned with setting any arbitrary numbers and looking at them. We want to move forward to a physical program.

MR. STEIN: I am not talking in terms of arbitrary numbers, sir. I am not saying that I don't agree with what you are saying philosophically, but we have a law we have to work with that the Congress has given us. Now, for years I think this statement and your point of view was made to the Congress--that we don't have numbers, that we accelerate the program and keep this from entering the municipality limits, that we accelerate the abatement program and this is what cleans up pollution. Sure. However, the Congress has indicated to us that they didn't believe we were moving fast enough. As a matter of fact if you look at the record, it indicated they thought we were losing ground with that approach. Therefore, they came up with this criteria standard requirement for us to set and enforce, and this is the job we have.

Now, as we have utilized these standards throughout the country, and again I am not applying it here, what this boils down to is setting some kind of number that we are going to enforce against. Now, the suggestion is we don't do that. I would like to know how we handle that with the mandate we have from the Congress to carry the program forward.

Again I am not arguing this point, because I recognize the difficulty of the problem we have to deal with.

MR. HOLBURT: Well, I think you simply handle it by recognizing the salinity problem in the Colorado is considerably different than the water pollution from industrial wastes and municipal wastes that you have in some of the eastern streams where you can set a number and control some of these things.

For instance, I have heard you look at that 10-year chart on several occasions and say the numbers speak for themselves. Well, those numbers don't speak for themselves. They are a combination of many different factors, of the flow of the river, the impoundment in the reservoirs and releases, the type of development, the rapidity with which development takes place. You have to analyze those numbers to know what they mean.

For instance, I expect that in the next couple of years we will get a little better water down at Parker because we have had a couple of good years on the Upper Basin and some improvement at Lees Ferry will pass through in 2 years and be reflected down at Parker. What doesn't make me happier, if you have a number that you set at present and then we go below it, are you going to say,"Well, that is fine, we are making progress"? I don't think we are.

The problem remains the numbers that we are going to get are going to fluctuate depending on conditions, and it is fruitless at this point to try and work with those numbers. I can only repeat that the proposition that you have to tell your people is that we are going to work on a physical program to meet the problem, and that is the answer. And at some later date when we know more about the programs, there may be some advantage in setting numbers, but it will be very divisive at the present time to try and set numbers. And we in the lower basin States don't see it as any particular advantage at this point either. I think Mr. Dibble yesterday was giving a pretty good, exact analogy about a speed limit and in terms of setting a number, and that is what people work for.

I hope that answers your question.

MR. STEIN: Well, I think your point of view is very clear. I don't want to prolong that. With your explanation, yes, these figures do speak for themselves. I think we need the explanation that you gave; I know these sources have put in pollution control.

But I would like to call your attention to one thing, and I think we all have this however we come out. If you say the setting of numbers is going to be divisive, what do you think the nonsetting of numbers is going to be? Do you think we are going to be welcomed with open arms with a lot of people who want clean water in the Colorado by the nonsetting of numbers or are we faced with a divisive result no matter what we do?

MR. HOLBURT: I don't think there is anyone that wants better quality water than the people in California unless it is the people in Arizona, and if we thought this was the thing to do we would be recommending it.

Could I ask you a question?

MR. STEIN: Surely.

MR. HOLBURT: You keep talking about enforceable. How would you enforce it? How would you enforce the numbers that you would set?

MR. DIBBLE: I was just going to ask him that too.

May I add to your question, as long as you have brought it up?

I thought we had gone into this in sort of some detail yesterday, that the problem on the Colorado River just doesn't lend itself to enforcement. It seems to me that the EPA staff in presenting the results of the report yesterday in effect said this, and it seems to me it is the key to the problem:

> The salt load in the Colorado River tends to be essentially a constant salt load in terms of tons, but the problem is that the amount of water moving downstream is gradually being less as the stream is depleted in terms of amount of water, which means that the concentration in the remaining water is more.

Now, how do you enforce on a problem like that? That is not an enforcement problem that can be handled by a regulatory agency, and I think that that is the real thrust that we have to--point we have to get across in a conference like this. It just doesn't lend itself to enforcement. The only solution to it is to take this all back out by some kind of a salinity control program, keep the salt from getting in or take it out.

MR. STEIN: Well, that well may be. That may be the result of enforcement.

MR. DIBBLE: Not of enforcement, but of a physical actual program.

MR. STEIN: That is what we have in all cases. I suggest, Mr. Dibble, that we have the problem in many, many streams in the eastern part of the country that you have indicated you have here on the Colorado. Again, I think we have this all over. For instance, we have taken streams like the Mississippi or the Missouri or the Ohio, which used to be free-flowing streams, and changed the regimen of those streams. To use a very clear example that I think most of you are aware of, the Ohio is a series of pools or in effect lakes; then you have a lock and the levels drop a little lower. Well, in the old days, when you had an industry or a city on the Ohio putting its wastes down in that swift-flowing stream, it certainly didn't have the kind of current, immediate effect that it does when it is put in a slack-flowing pool. So this is the problem we are facing all over.

I think we are here to try to develop with you a technique of getting that. I ask you again to examine the position you have. The question is what approach we take. I think that Mr. Armstrong indicated he adopts the need for numerical standards, but doesn't think we are quite ready. The EPA thinks we might be ready for those pretty soon or perhaps now. As I understand the position that you just gave, you are not sure we will ever need numbers; rather we have to go back with the notion that we are all going to put our shoulder to the wheel and reduce salt pollution as much as possible. Is that the result of what you have come out with?

MR. DIBBLE: Right.

MR. STEIN: All right. I understand that position. But may I suggest to you, sir, that I am not sure that the adoption of that solution wouldn't create as much divisiveness as any other.

MR. HOLBURT: In other words, it is simply a deferment of it. We are not saying whether we need it or don't need it; maybe we do sometime in the future, but defer it indefinitely.

MR. STEIN: But right now you are deferring it indefinitely?

MR. HOLBURT: Right.

MR. STEIN: Right. I understand. Thank you very much, sir.

MR. HOLBURT: You are welcome.

MR. DIBBLE: Mr. Chairman, the next one from California who would like to make a statement is David Kennedy of the Metropolitan Water District.

DAVID KENNEDY, ENGINEER
METROPOLITAN WATER DISTRICT
OF SOUTHERN CALIFORNIA
LOS ANGELES, CALIFORNIA

MR. KENNEDY: Mr. Chairman, my name is David Kennedy. I am an Engineer with the Metropolitan Water District of Southern California. I am here today representing Frank Clinton, our General Manager.

We have a brief statement of about 3-1/2 pages and with your concurrence, Mr. Chairman, I will read the statement.

MR. STEIN: Go right ahead.

MR. KENNEDY: The District has worked closely with California's Colorado River Board in reviewing the EPA report, and we concur fully in the comments presented by Mr. Holburt.

D. Kennedy

Our statement today is intended to supplement Mr. Holburt's comments.

The Metropolitan Water District has been bringing water from the Colorado River to its service area within the Coastal Plain of Southern California since 1941. For the past several years, diversions have been at essentially the full capacity of the Colorado River Aqueduct, which is 1.2 million acre-feet per year. This supply provides approximately 43 percent of the total water supply used in the District's service area. There are now 124 cities within the District and the total population is presently 10.3 million.

The salinity of Colorado River water during the 30 years of the District's operations has fluctuated considerably but has always been higher than desirable. I think this gets to one of the points that you were quizzing Mr. Holburt about. The average salinity at the intake to the District's Aqueduct at Lake Havasu over the 30-year operating period was 684 ppm. The salinity has ranged from a low of 487 ppm in January 1953 to a high of 842 ppm in January 1957. For the past year it has averaged approximately 741 ppm.

Let me digress a moment, Mr. Stein. The chart that the EPA fellow showed yesterday I believe showed that at Parker Dam the salinity in 1970 was 784 ppm, is that correct?

And that is where our diversion is. So that 784 in 1970 compares with 741 over the last year.

Several agencies, including EPA, have made projections of future salinity levels of Colorado River water. While there are some differences in the specific projected levels, all of those studying the problem agree that salinity will increase, unless corrective measures are undertaken.

In viewing this situation, the one encouraging factor is that specific corrective measures have been identified which could probably offset the projected increase and possibly even reduce salinity below present levels. The EPA report describes a broad range of salt reduction measures, which, at the reconnaissance level, appear to be economically justified. The present need is to determine more precisely the feasibility of these individual projects and to develop a comprehensive salinity control program.

With reference to the three recommendations in the EPA Summary Report, the District agrees with Numbers 1 and 3. We disagree, however, with Number 2, that specific numerical criteria be established at key points throughout the Basin by January 1, 1973. On this issue, the District shares the view of many other agencies that the attempt to establish such criteria would lead to unnecessary contention among the Colorado

River States and would not be a constructive step toward resolving the salinity problem.

The District is further concerned by an apparent dilemma in the general concept of setting salinity criteria in the Colorado River Basin. It is clear that present levels are far greater than desirable and are causing significant economic problems. It is also clear that until the feasibility of specific control measures is determined we will not know what levels can be maintained. If the adopted values were in the range of salinity levels presently found in the Lower Basin, the implication would be given that any value less than that adopted is acceptable, and during periods in which normal fluctuations caused the actual salinity to be less than the criteria there would be less impetus to take long-range corrective actions. That is a situation I think we are facing right today. On the other hand, if the criteria were set at levels considered acceptable or desirable from the water user's standpoint, the criteria might be unattainable and hence would tend to be disregarded.

On this point, Mr. Chairman, you asked Mr. Holburt for a benchmark. I think we probably passed the acceptable benchmark about 60 years ago when we went past 500 ppm. So that if you get up and start talking about 750 ppm, we are concerned that the implication will be given that any time you are less than that adopted value everything is all right.

It is the District's belief that the most pressing need is to proceed with determining the feasibility of individual salinity control projects. Based on information contained in the EPA report, there is reason to expect that many of these projects will be found feasible and that a comprehensive basinwide salinity control program can be developed. Recognizing that salinity levels in the Lower Basin will probably be higher than desirable no matter what control measures are undertaken, the program of implementation should include all salinity control projects which are economically justified.

That completes our prepared statement. I might make one more comment as to another way of framing the objective that we are all pursuing here in the basin.

We have talked about that we need some standard to shoot for. I think Mr. Freeman yesterday presented two alternative approaches to this general problem of salinity.

Another way of stating our position would be, we think that all of the salt that can be removed from the river economically should be taken out, that we are far past any acceptable or desirable level, so that if we want to set objectives we might set them in terms of removing X tons of salt from the river rather than maintaining any particular level in the river.

I would be happy to answer any questions.

MR. STEIN: Are there any comments or questions?

I would like to thank you, Mr. Kennedy, for an excellent statement. I think again that while we may differ on the methodology--I don't know that we really differ; I am here to learn--the objective we have is certainly the same.

I would like to just point out that I will agree with you that your figure of 500, which we went above a long time ago, was the kind of figure that was probably over a desirable level. But I would suggest to you that in making your statements on what you are doing in taking the water out of Lake Havasu and mentioning the number 500, in order to prove and illustrate your points at every stage you did, in fact, use numbers, and that is what we are dealing with, are these numbers.

I also would suggest that just going below a designated number does not mean that you are doing a tremendous job, because of fluctuations, or if you go above it, you are automatically going to have a violation. Any approach with numbers like that is going to be mechanical, and you are going to get into trouble.

I notice Mr. Beverly from the uranium milling industry is here. I remember we had the same problem with numbers in dealing with uranium in certain tributaries. When the radium level got down to the Public Health Service Drinking Water Standards a lot of people said, "Boy, that is low enough; let's stop." Our notion was, "Nonsense." I believe in no radiation. At least, I am one of those who believe in the cumulative effect of radiation; that the best kind of radiation is as little and as close to background level as possible. Putting that thesis forward and with the cooperation of the industry, we reduced it, as I pointed out, to about one-third of Public Health Drinking Water Standards.

So in setting a number for control measures, I don't think that you necessarily have to think you have achieved the millenium once you have gotten below that number and you can't push back. At the same time, if you have a fluctuation and you have an aberration above it, I think you should be able to set something flexible enough not to lower the boom if that happens to be out of control. And I am merely suggesting that as a technique. Let me try this again on you, and I don't necessarily expect an answer. This may be a rhetorical question or comment.

Mr. O'Connell points out to me that we are obliged under the Federal law to deal in terms of numerical requirements in States or requirements in States; maybe numerical is not the word. If States don't adopt it with us, then we are obliged to do that ourselves under the law.

What I am trying to do is see if we can arrive at a control mechanism with the States that will enable us to roll back the salinity of the Colorado River, enable us to comply with appropriate Federal law that we are operating under, and also allow all interested observers to have some kind of benchmark to see if the States or we are doing our job.

MR. KENNEDY: I think my comment on that is that this particular benchmark that you would be choosing is on the one hand misleading because it is not a useful benchmark. And the second point is, I think it is going to serve to defer taking those actions that we all think should be taken. We are all in agreement, I think everyone in this room, that the salinity of the Colorado River should be reduced, and the objective or the question is how are we going to meet that. Now, you feel that by setting these standards that will be helpful. I think we feel that it will be just the opposite, that it will mislead us, actually, by giving us a false benchmark.

MR. STEIN: I understand what you are saying. Let me clarify a personal position. I don't have any feeling on this now.

What I do suspect is that this isn't the first time that these views were presented to EPA. No doubt you gave them to Mr. DeFalco and the Regional Director and the staff many times. Presumably that staff in EPA was not persuaded, or we would have got this report from EPA.

What I am here looking for is to see, in the face of that, whether we can come to an accommodation and arrive at an agreed-upon position that you and we can both adopt to go forward. That is the only thing I am recognizing.

MR. KENNEDY: Let me suggest what that accommodation might be. Maybe we could all agree to defer this setting of standards indefinitely until more information is known.

(Laughter.)

MR. STEIN: I am not--again, Mr. Armstrong suggested 3 years; I know you don't, but he needs it for study. One of the approaches, and I am making no suggestion on this at all, because one of your approaches might be in terms of setting a requirement or an objective to get a certain amount of salt out of the river, which was pointed out. That might be an approach.

What I am trying to do here, the reason I am going with you, because I think you are very sensitive and responsive to the problem. I am trying to look for a possible technique that both you people and the Federal people can sign off on so we can get on with the program.

MR. KENNEDY: I just suggested one to you. Let me--

MR. STEIN: I know. But I would suggest that indefinite postponement may not be quite the way to arrive at an accommodation, sir.

MR. KENNEDY: How about postpone for a period of 3 years, and then pull the conference together again and see where we all are?

MR. STEIN: Well, that might be. But what is to prevent an increase in the interim? Do you need certain objectives to see how many pounds have been reduced during those 3 years?

I don't want this to even be represented as my position, certainly not an official position. I am just giving you the kind of ideas that we possibly can get to to arrive at an accommodation on this.

MR. KENNEDY: Let me put it not on the basis of the recommendation in the EPA report, which is what we are really talking about.

I think you can summarize our position by saying that we feel, first, that the setting of standards is a misleading type of approach. It misleads all of us.

Secondly, and a point that there hasn't been much conversation about, it would take a great deal of staff time. By staff time I don't mean just the engineering time, but the time of a great many people who could better use that time pursuing this salinity control program. I think if we spend all those hours arguing about what the numbers should be, we would wind up at the end of it without having attained very much, and it would not have accomplished as much in the salinity control program as we could have.

MR. STEIN: I couldn't agree with you more on that statement, although I come out a little differently. I see people in the Federal Government, I won't speak about the States, spending an inordinate amount of time arriving at these numbers— time that could be more profitably spent. I have the feeling that I could, or after a couple of hours discussion, you could come up with as good a number, and maybe we can do that as well today as we could 3 years from now and go on with the job.

MR. KENNEDY: I think any number you come up with, though, would be a misleading number, and that is where we are concerned.

MR. STEIN: I understand your view.

MR. KENNEDY: I might just comment in concluding our remarks that we are probably the first water user you have heard from. I think the others have been Federal and State agencies, not those actually using the water, and there may be some significance to the fact that those who are actually affected, as our District is very much, feel the very same way.

MR. STEIN: Are there any other comments or questions? Yes.

MR. DICKSTEIN: One comment.

You have several years of data at Parker Dam, and you gave us a high and a low. What has been the trend analysis of this data?

MR. KENNEDY: There is very little discernible trend over the 30-year period that we have a record. It has gradually, you might say, increased, but the swings have been so significant up and down that just plotting the record up and down it is hard to find that trend that everybody says is there. Now, you can plot a double mass diagram and think you find something, but it is not quite as apparent as some people have implied.

Now, over the last year the salinity at Parker has actually decreased by about 10 ppm. We are at about 740 right now. We have been as high as 840.

MR. DICKSTEIN: Thank you.

MR. DIBBLE: Mr. Stein.

MR. STEIN: Yes.

MR. DIBBLE: You said, if I understood you, that we are looking for a technique for protecting the quality of the river, and then in about the next breath you were talking about lowering the boom. And I really was wondering whether you are looking for an enforcement technique or whether you are looking for a way to keep the quality of the Colorado River under control. It seems to me the two are different.

MR. STEIN: Well, if they are, we would like to hear. Our objective is to keep the river under control. Now, we recognize this, and I think, Mr. Dibble, you made this point. I thoroughly agree with the point. I hope I am not talking about lowering the boom.

I think the problem that we have on the Colorado River can possibly be likened to our dealings with acid mine drainage in the East. The question raised is whom do you proceed against; whom do you enforce? The difficulty that I think we have had in these cases is that we do not have another mechanism--or if we do, it hasn't been utilized--to bring the States together and grapple with this problem. And in all candor, I would say that this is why we at a conference of this type have dealt with those tailings piles. It may have something to do with pollution when it blows into the stream. But after we had cleaned up, as I indicated--I think the States, the industry, we, and the AEC did not only a reasonably good job, but an outstanding job reducing the radium discharges and content of the Colorado River and its tributaries--we were faced with the residual of these tailings piles. They wouldn't go away, except to blow away, and no one seemed to deal with them. So we were given the job or we took it upon ourselves because we just couldn't walk away.

Now, again, here is the way I see the problem, and I think this is a very important one from our point of view. I hope you will agree with it.

MR. KENNEDY: May I comment on that--

MR. STEIN: I ask you to look at the Colorado River. We find that the radiation problem there--as I indicated a reasonably progressive job is being taken on municipal and industrial wastes--the big--

MR. KENNEDY: May I comment--excuse me, go ahead.

MR. STEIN: Please, just a minute.

The big source that we are dealing with in the degradation of the water quality, or the condition in the river which is causing the water quality to be below what we would like to see, is the salt. Now, we have tried to use our most flexible tool, using this mechanism of a conference to get together and try to reach an accommodation. The advantage of this technique, if nothing else, is that all the States get together around the table with us and we don't go off on a problem dealing with this separately, either Federal or State.

Now, I suggest--and again I spent, you know, a career on these water-diversion cases, both here and in the Great Lakes--that possibly the most rapid way to come to an accommodation on the solution is to keep a conversation or dialogue going between the States and us, as we have here. It is very easy, as you people know--and I don't have to tell you in California and Arizona--to get beyond the point of no return with this water problem where you are just locked in. This is why we are using the conference.

MR. KENNEDY: That is the particular point I would like to comment on, Mr. Stein.

The Colorado River salinity problem is a unique problem. The particular point that we are concerned about on this accommodation is that the States have now reached an accommodation for the first time, or with the exception of the Colorado River Basin bill that was passed in 1968 after a great struggle. This is an issue on which the Colorado River States are united, and that is quite an unusual thing, as you are probably aware. Our Chairman, Joe Jensen, who has been involved in Colorado River matters for a long, long time, made a comment to some Upper Basin people here about 2 weeks ago to the effect that we have got to work our problems out together. He said,"We have spent many years fighting you people and we are not going to do it that way in the future. We would like to work this problem out in cooperation."

Now, here you have a problem that the seven States are united on, and what we would ask for is EPA's support in getting behind that agreement that we all have. We feel we see the solution to this problem. We ask for your support.

MR. STEIN: I think this goes both ways. I might say if you are united on the Colorado River it is not just unusual, it is unique. (Laughter.)

Are there any other comments or questions?

MR. DICKSTEIN: I just have one comment on the side here. It seems to me that the enforcement conferences we have had on the Colorado River have really achieved a monumental event here in helping unite the people.

MR. STEIN: Are there any other comments or questions? If not, thank you very much.

MR. KENNEDY: Thank you.

MR. STEIN: It has been very helpful.

MR. DIBBLE: Mr. Chairman, the next one that would like to be heard from California is Mr. Lowell Weeks, who is the General Manager and Chief Engineer of the Coachella Valley County Water District, referred to yesterday as the Cocachella Valley. (Laughter.)

LOWELL WEEKS

GENERAL MANAGER AND CHIEF ENGINEER

COACHELLA VALLEY COUNTY WATER DISTRICT

COACHELLA, CALIFORNIA

MR. WEEKS: Mr. Chairman and gentlemen. Coachella Valley has been called many things down through the years, but we still consider it quite an important part of the Colorado River Basin.

My name is Lowell Weeks and I am the General Manager and Chief Engineer of the District, and on behalf of our Board of Directors I want to thank you for this opportunity to appear in front of this conference. You have the written statement in front of you and I will just try to briefly bring up some of the important points as far as we are concerned in the Coachella Valley.

Many people do not know the location of Coachella Valley, and unfortunately when I am away from home I have to say Palm Springs is located within Coachella Valley. Then everybody knows where it is.

The average rainfall is so slight in Coachella Valley that it is practically disregarded, and the sole dependence for water in growing crops is placed in irrigation. The source of this supply lies principally in the rainfall and the melting snows on the high mountain peaks at the northwestern end of the valley, and since 1949 in a supplemental supply from the Colorado River diverted at Imperial Dam through the All-American Canal to Coachella Valley, a distance of 150 miles, where it is distributed onto the farms.

The development of the valley began in 1888 when they found groundwater below the surface of the ground. However, with the installation of wells, the water table decreased, so it was not long before the farmers recognized they had to have a new source of water.

The Coachella Valley County Water District was organized in 1918 to carry out water conservation policies and to seek an additional supply of water. The Water District is a public agency of the State of California and its functions and powers are governmental in nature. Since 1918 the District has entered into six separate and distinct contracts with the United States, all dealing with a supply of water from the Colorado River. These contracts were entered into in 1920, 1921, 1929, 1934, 1947, and 1963. The early contracts were brought into existence after the passage of the Kinkaid Act by the Congress in May 1918 under which the District made contributions to the United States for its early surveys, investigations and reports, looking forward to the construction of what we now call Hoover Dam and the building of the All-American Canal to deliver water into the Coachella and Imperial Valleys.

The 1934 contract was a water delivery and repayment contract which provided for construction of capacity in the All-American Canal Project to deliver water into Coachella Valley.

The 1947 contract was a distribution system contract. It provided for the physical works to take water out of the canal and deliver it onto the land. All of the work contracted to be performed by the United States has been completed and Colorado River water is now being used for irrigation in the valley. This took a long time. The works were turned over to the District for operation and maintenance in March 1949, 29 years after the date of the first contract between the United States and the District.

The District diverted 466,000 acre-feet of Colorado River water during 1971 for irrigation water service to more than 60,000 acres in the Valley. In addition to providing irrigation water service, the District serves domestic water service to an estimated 25,000 persons, has constructed and is operating a wastewater reclamation plant, conveys the drainage discharge from over 1,900 miles of on-farm drainage tile lines to the Salton Sea, and constructs, operates, and maintains flood control facilities.

The increasing salinity of the Colorado River is of great significance to the farmers and other citizens of the Coachella Valley, and the District has been active for many years in seeking to limit salinity increases and to minimize the impact of the high saline Colorado River water. The District has participated with the Colorado River Board of California in its activities to reduce the salinity of the Colorado River by effecting a Colorado River Basin Salinity Control Program, and fully supports the Board. We are pleased with the completion and distribution of the EPA program. We believe that it may be of assistance in obtaining a Federal program to control the salinity of the Colorado River.

We believe that the report's Recommendations 1 and 3 will help in achieving that goal; however, Recommendation 2, calling for the establishment of specific numerical criteria throughout the basin by January 1, 1973, would tend to negate the beneficial impact of the other two recommendations.

Accordingly, we strongly recommend that the Environmental Protection Agency take no further action with regard to the Recommendation 2 of its report. Further, we endorse the recommendations of the Colorado River Board of California pertaining to that report and commend them to your attention.

Just to add a little to it, I have listened to the comments of the Chairman, to each of the other two participants--

MR. STEIN: I am not going to say against. (Laughter.)

MR. WEEKS: I would just like to bring one thing to mind. When you mention the enforcement of the uranium, I think they were very definite, you knew where they were, you could go out and draw a line around them and had no problem whatsoever. However, salinity in the Colorado River is a vast, complex, and, as you know, very difficult program.

The only comment I would like to make to your idea of setting standards, I am afraid EPA's staff, which they did put out an excellent report, in which you said that they evidently in all the staff hearings did not abide by the decisions or wishes of the States, I am afraid they are oriented, as most sanitary engineering, as most public health people, to a number. Once you have a number, man, we have something. Anybody that goes below it, we can run out and spank them. I don't know who you are going to spank in this.

I think the whole concept must be taken out of the idea of having something for enforcement, and rather than spend money for employees to check the river for enforcement, let's put all this money into building salt control works and if you want a figure, let's take 5 million tons of salt a year out of the river.

That's our comments, Mr. Chairman and gentlemen.

MR. STEIN: Any comments or questions?

MR. DICKSTEIN: Mr. Weeks, what type of irrigation practices do they use on your valley? Do they use mechanical means or the hose soaking method or what?

MR. WEEKS: In the Supreme Court hearing between California and Arizona, the special master found out that we have the most efficient irrigation in the United States, all underground pipeline, every drop of water is metered the same as your domestic water meters.

MR. DICKSTEIN: It can be done, then?

MR. WEEKS: Yes, it can.

MR. DICKSTEIN: Thank you.

MR. STEIN: Are there any other comments?

That was a very excellent statement, Mr. Weeks. I agree with you that it may be a little more difficult finding the sources and controlling them with salinity than it was with uranium, but I am also convinced that the organization or ingenuity indicated by your statement, and going down the line with Mr. Kennedy and Mr. Holburt, would give the kind of organizational ability that would be able to deal with a problem like this.

MR. WEEKS: I would like for you--

MR. STEIN: You have got good men.

MR. WEEKS: I would like for you to meet with the Bureau of Reclamation, see to it. They have got all the money that is required to get the work started.

MR. STEIN: Let's recess for 10 minutes.

(RECESS)

MR. STEIN: Let's reconvene.

Mr. Dibble, would you proceed.

MR. DIBBLE: Mr. Chairman, I would like to introduce Mr. Robert Carter, the General Manager of the Imperial Irrigation District, our largest irrigation district in California.

ROBERT CARTER

GENERAL MANAGER

IMPERIAL IRRIGATION DISTRICT

IMPERIAL, CALIFORNIA

MR. CARTER: Thank you, Mr. Dibble.

Mr. Chairman, members of the conference committee.

My name is Robert Carter and I hold the position of General Manager of Imperial Irrigation District in Imperial, California.

Imperial Irrigation District, a publicly-owned water and power utility of California, welcomes this opportunity to present these comments on the Environmental Protection Agency's report, "The Mineral Quality Problem in the Colorado River Basin," dated 1971.

The District performs three functions: (a) Diversion and delivery of Colorado River water for irrigation, industrial and domestic uses, there being no other usable water available from any source; (b) Operation and maintenance of drainage canals and facilities; and (c) Generation, transmission and distribution of electrical energy to a 7,500 square mile area, including the area that Mr. Weeks's district is located that preceded me.

The District diverts water from the Colorado River at Imperial Dam and transports the same through the All-American Canal for a distance of 80 miles into its 1,650-mile canal system to serve 6,000 headgates. These in turn deliver water to 553,000 acres for agricultural use, on a single-crop basis, and to 7 incorporated cities for municipal and industrial purposes.

The District is one of the largest irrigation districts in the United States and is the largest single diverter in the entire Colorado River system. Its diversion for the year 1971 was 2,939,000 acre-feet.

The District further provides a 1,375-mile drainage system throughout its service area which acts as a collector for surface regulation and receives subsurface brine effluent from the 16,815 miles of subsurface tile installed in 369,804 acres of land through the soil profiles in an effort to maintain a favorable salinity balance. The increasing salinity of the Colorado River is of great concern to Imperial Irrigation District and the farmers the District represents.

The District fully supports the studies, reports and recommendations of the Colorado River Board of California which pertain to the salinity of the Colorado River and it has participated with the Colorado River Board in urging the establishment of a Colorado River Basin Salinity Control Program.

The District is pleased with the completion of the Environmental Protection Agency's report, "The Mineral Quality Problem in the Colorado River Basin," and we urge that the agency use its influence, also, to obtain a Federal program to control the salinity of the Colorado River. We concur in the report's Recommendations 1 and 3 and believe that they will assist in achieving a goal of a Federal Colorado River Basin Salinity Control Program.

We do not agree with Recommendation 2, however, which calls for the establishment of a specific numerical criteria throughout the basin by January 1, 1973, with the criteria predicated on a 1,000 mg/l concentration at Imperial Dam, our diversion point. It is our opinion that this recommendation would make it difficult to achieve a basic objective of limiting salinity to or below present levels at Imperial Dam. Furthermore, if a numerical value, such as 1,000 ppm, is established, it may very well act to prevent the adoption of measures that would reduce the river's salinity below present levels which, in our experience, certainly are more harmful to our water users. Accordingly, we believe that the setting of a specific numerical criteria should be deferred at this time until a salinity control program is effected and the impact of the program is known.

Therefore, it is the recommendation of Imperial Irrigation District that the Environmental Protection Agency take no further action with respect to Recommendation 2 of its report, "The Mineral Quality Problem in the Colorado River Basin." And let the record show that we fully support and endorse the recommendations made by the Colorado River Board of California pertaining to that report.

I would like to make one other comment that is not included in the paper but I think is pertinent which deals with the incoming water that I made reference to, the 2,900,000 acre-feet in the quantity that we diverted in 1971. Of course it differs each year. But we do establish a set of figures in that respect to determine how much salt is coming into the valley, and by figures that we have developed we have approximately 4 million tons of salt enter our system each year, and the 16,000 miles of subsurface tiling that I made reference to transports 4,600,000 tons of salt away from the soils into Salton Sea. We have no return opportunity of water going back to the river.

But my point is simply this. If we are able to pick up 4.6 million tons of salt from our system, I agree with Lowell Weeks, the speaker who preceded me, that your obligation should be to remove the 5 million that he made reference to.

Thank you. (Laughter.)

I will be glad to answer any questions.

MR. STEIN: Are there any questions or comments?

Again let's try this, because I think maybe we are discerning a pattern here that possibly we can work on. I think to expand the previous speaker's comments, and I think this is not just Mr. Weeks but Mr. Kennedy and Mr. Holburt, what you say, I would like to refer to one sentence in there because I think maybe this can help us get around first base:

> Accordingly, we believe that the setting of a specific numerical criteria should be deferred at this time until a salinity control program is effected and the impact of the program is known.

O. K. Now, that to my mind doesn't talk about necessarily indefinite postponement, but postponing until you are going to come up with a salinity control program.

Now, let's take the other ideas that were thrown out by your earlier California speakers here. If we are talking in terms of developing a program for removing X pounds of salt from the river and if we are talking in terms of that obviously over a period of years, could we--and I am just, again, putting this out as a possibility--indicate or come up with a specific time where we will have an objective for coming up with the salinity control program to reduce the salt and determine how long that would take and then recognize when we would find that the impact of this would become effective so we can consider what the impact of this soil reduction would be before we move on to the next step?

MR. CARTER: Well, it would seem to me that the broad data is available in certain forms over many years past and that it certainly wouldn't be unreasonable to defer the establishment of a maximum, if we are talking about Imperial Dam, because I think you have to establish the maximum on the District at the tail end of the system. You certainly can't establish a maximum upstream because they will contribute to the demise or the betterment of it, if you please, if they divert back to the river.

But I certainly agree with what Mr. Kennedy and Mr. Holburt and Mr. Weeks previously stated here. I think it would be premature at this time to establish it. Why not put the operation in gear, if you please, and get the position of doing something started, get the benefit of the operation of a program whereby we might be able to better this 1,000 ppm? The testimony that I have heard here this morning all relates to 1,000 ppm. We certainly aren't happy with 1,000 ppm, particularly when we take into consideration that this 16,000 miles of tile has cost the farmers of Imperial Valley $34 million.

MR. STEIN: Yes. The only thing--I don't direct this directly to you, Mr. Carter, but to the conferees and the other people who have made statements. Again let me refer to your statement.

> We believe that the setting of a specific numerical criteria should be deferred at this time until a salinity control program is effected and the impact of that program is known.

I would suggest that we might give some consideration to indicating, if this is the approach, how long it will take us or what date we might set for the development of that salinity control program and what date we might expect--and what the objectives of that salinity control program are, perhaps in reduction of pounds per day of salt, and when you could reasonably expect or possibly as an objective expect the results to be known. I just throw that out as a possibility.

Any other comments or questions?

If not, thank you very much.

MR. CARTER: Thank you, sir.

MR. STEIN: Mr. Dibble.

MR. DIBBLE: Mr. Chairman, the last person I would like to introduce from California is Mr. Wayne MacRostie, who is representing the State Department of Water Resources.

Mr. MacRostie.

WAYNE MAC ROSTIE, CHIEF
INTERSTATE PLANNING BRANCH
CALIFORNIA DEPARTMENT OF WATER RESOURCES
SACRAMENTO, CALIFORNIA

MR. MAC ROSTIE: My name is Wayne MacRostie. I am the Chief of the Interstate Planning Branch of the California Department of Water Resources. I am here today representing Bill Gianelli, our Director, who was not able to make the meeting and sends his regrets.

The Department of Water Resources is very much concerned about the Colorado River. It now comprises 75 percent of the water supply of Southern California. When our State water project becomes operative after 1990 the Colorado River will still supply over half of the water needed by our southern counties.

The Department of Water Resources is also very much concerned about the salinity problem in the Colorado River. We have been working very closely with the State Water Resources Control Board, Mr. Dibble's organization, with the Colorado

River Board, in order to find ways that are reasonable and practical to solve the problems that result from this increasing salinity.

We wish to endorse wholeheartedly the statement that the Colorado River Board has submitted today and the discussion that ensued after Mr. Holburt's statement. We can also agree with the statements of the District people that appeared before me.

We feel that the program that has been outlined by the Bureau of Reclamation to help overcome the salinity problem of the Colorado River is a most worthwhile program and should be pressed with all diligence, and we feel that it would be a serious mistake at this time to set numbers as objectives, criteria, or whatever you wish to call them. We think the emphasis should be on developing a program to find a physical solution of the problem.

Thank you very much, Mr. Chairman.

MR. STEIN: Thank you.

Are there any comments or questions?

If not, thank you very much, sir.

Mr. Dibble.

MR. DIBBLE: Mr. Chairman, the only other matter that I would like to present to the conference on behalf of

California is this, that California submitted its formal comments on the draft of the report many months ago and those were included in Appendix D of the EPA report.

There are two additional letters that I would like to have added to the record representing the position of California.

First is a letter dated September 3, 1971, from Kerry Mulligan, Chairman of the State Water Resources Control Board, to the Honorable William D. Ruckelshaus, summarizing California's thoughts on the Colorado River salinity problem.

The second is a letter dated December 23, 1971, from William D. Ruckelshaus, Administrator of the Environmental Protection Agency, to Mr. Mulligan.

And I would request that those be made a part of the record as though they had been read.

MR. STEIN: Without objection, that will be done.

(The above-mentioned letters follow:)

STATE OF CALIFORNIA—THE RESOURCES AGENCY
RONALD REAGAN,

STATE WATER RESOURCES CONTROL BOARD
ROOM 1140, RESOURCES BUILDING
1416 NINTH STREET • SACRAMENTO 95814
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KERRY W. MULLIGAN, *Chairman*
E. F. DIBBLE, *Vice Chairman*
N. B. HUME, *Member*
RONALD B. ROBIE, *Member*
W. W. ADAMS, *Member*
JEROME B. GILBERT, *Executive Officer*

SEP 3 1971

Honorable William D. Ruckelshaus
Administrator
Environmental Protection Agency
Washington, D. C.

Dear Mr. Ruckelshaus:

Summary of Colorado River Salinity Problems

The salinity of the Colorado River under natural conditions was high. Activities by man have significantly increased the salinity of the River, and it will continue to increase unless control actions are undertaken. Salinity is a basinwide problem for the seven states in the Colorado River drainage area. It is also a major problem for Mexico, as evidenced in the statements by the President of Mexico that the salinity of the Colorado River is the single most important issue between the United States and Mexico.

The Bureau of Reclamation, the Environmental Protection Agency and its predecessor agencies, and California have been studying the salinity of the Colorado River for many years. These studies have identified, on a reconnaissance level, a number of salinity control projects that have the capability of preventing several millions of tons of salt per year from entering the river system. A major salinity control program was agreed to by the Bureau of Reclamation and the former Federal Water Quality Administration at the end of 1968; however, it was never carried out.

Recently, all seven Colorado River Basin states joined together in urging the commencement of a Colorado River Salinity Control Program as a major activity, and the preparation of feasibility reports for specific projects. This program has been endorsed by the State Department as an urgency matter because of the need to negotiate a new agreement with Mexico concerning the River's salinity. Secretary Rogers has written to Secretary Morton urging support of such a program. The Bureau of Reclamation has transferred funds within its own budget to commence feasibility studies and will shortly be coming up with a major action program.

In April, 1971, the Environmental Protection Agency issued a draft of its long-awaited report for review by the seven states. One of the recommendations advised establishment of specific numerical salinity criteria in the Colorado River Basin. This recommendation was opposed by all of the basin states in their comments on the draft report. It is our understanding that, based upon its national policy, the EPA plans to recommend in its report specific numerical criteria for consideration by the conferees at a meeting to be held in the fall. California urges that numerical standards not be recommended at this time. This state uses more water than the other six states combined. We are making this recommendation in full recognition of our position of being the lowest on the river, thereby receiving the major impact of the salinity problems of the basin.

If the attempt to establish numerical criteria now would be beneficial and helpful with respect to the Colorado River salinity control problem, we would be for it; however, such a program would not be beneficial at this time for the following reasons:

1. After much time and effort, all the basin states and the Departments of State and Interior are unified in proceeding on a positive program to help correct the salinity problem. We urge wholehearted support of the Environmental Protection Agency in this program. Any attempt to establish numerical salinity criteria could be divisive and would harm this unified effort.

2. The EPA draft report has recognized that more information is needed on the feasibility and capability of the salinity control projects that have been identified to date. Thus, it would not be possible to rely on such projects as being adequate means of achieving desirable salinity standards until feasibility studies on the projects have been completed.

3. In the absence of any salinity control program, the only way in which numerical criteria could be enforced would be by taking actions against water users in the Upper Colorado River Basin states. These states could view any attempt to establish numerical criteria as an attempt to stop their economic development and also as being in opposition to the seven-state Colorado River Compact.

4. The Upper Basin states have indicated they will use all political and legal tools at their disposal to block the

setting of numerical criteria. This could result in years of adversary type proceedings and little action on physical control projects.

As an alternative to recommending numerical criteria, we recommend that at meeting of the states the EPA take the following approach:

a. Recommend as a goal the maintenance of salinity at or below existing levels;

b. Note that all parties support a major Colorado River Salinity Control Program;

c. Offer its support and expertise to assist in the program; and

d. Defer for a specified period of time the establishment of numerical criteria pending sufficiently rapid development of the salinity control program.

Sincerely,

Kerry W. Mulligan

Kerry W. Mulligan
Chairman

cc: Wayne MacRostie
Myron B. Holburt

JBG/KWM:kir

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

Dec 23, 1971

Honorable Kerry D. Mulligan
Chairman
State Water Resources Control Board
State of California
Sacramento, California 95814

Dear Mr. Mulligan:

This is in further response to your letter of September 3, 1971.

The issues discussed in your letter regarding the Colorado River salinity problems provided valuable insight into their various aspects. My staff and I have reviewed in-depth the present situation in respect to the issues you presented. It would appear that the position advanced by you and that of the Environmental Protection Agency are not far apart.

A major program for the control of salinity in the Colorado River Basin will be necessary to prevent additional degradation of the water quality as the Basin is developed further, and to reduce the present salinity levels in the waters of the Basin. It is noted that a major salinity control program has the support of the various States concerned. Certainly, EPA within its resource constraints will provide support and expertise to assist in this program.

As you are aware, the question of setting numerical criteria for salinity in the Colorado River Basin has been under consideration for some time. It has been delayed pending the development of additional information on the salinity concentrations in the waters of the Basin, the sources of the salinity, and methods for the control of the salinity sources. While there is no question that additional information should be developed, we believe that data accumulated by the Colorado River Basin Water Quality Control Project furnishes a basis for the adoption of a numerical objective for salinity levels in the Basin. Such an objective is necessary as a guide in the development of water quality standards for the Colorado River and its tributaries and for the implementation of a salinity control program.

The joint Federal-State "Conference in the Matter of Pollution of the Interstate Waters of the Colorado River and Its Tributaries" will be reconvened in the near future. The Colorado River Basin Water Quality Control Project will present its report containing action recommendations to the Conferees at that time. It is anticipated that the Conferees will resolve the various issues so that the design and implementation of a salinity control program and the establishment of salinity water quality standards for the Basin can proceed without delay as a coordinated effort.

I am essentially in agreement with the four points outlined in your recent letter. I also believe that the course of action, which we proposed as a joint State-Federal program should provde for both improved water quality in the Colorado and maximum beneficial use of the water resource. You may be assured that we want to work with the several States in finding practical and constructive solutions to the long term problem of the Colorado.

Sincerely,

William D. Ruckelshaus
Administrator

MR. DIBBLE: That is all.

MR. STEIN: Thank you very much for California's presentation. It has been very helpful indeed.

May we call on Colorado next. Mr. Rozich.

MR. ROZICH: We will use the same format as our colleague from California used in calling those people from the State of Colorado that have indicated that they wish to make a statement.

First is Mr. Roland Fischer, who is Secretary-Engineer of the Colorado River Water Conservation District.

ROLAND C. FISCHER
SECRETARY-ENGINEER
THE COLORADO RIVER WATER CONSERVATION DISTRICT
GLENWOOD SPRINGS, COLORADO

MR. FISCHER: Thank you, Mr. Chairman.

I am Roland Fischer, Secretary-Engineer of the Colorado River Water Conservation District at Glenwood Springs, Colorado.

The Colorado River Water Conservation District is an organization of western Colorado composed of all of 12 and parts of three more western Colorado counties that are the principal headwaters of the Colorado River in Colorado. This includes the Yampa, the White, the mainstem Colorado, the Gunnison and a part of the Dolores. We are governed by a Board of 15 men appointed by the County Commissioners of those counties.

I have distributed copies of the statement and I will now read it, with some small additional comment.

The Colorado River Water Conservation District recognizes that there is a mineral quality problem in the Colorado River Basin and that the problem must be addressed. The solution to the problem will result from cooperative effort among the water users and water quality people of the seven basin States and Federal agencies.

The waters of the Colorado River Basin are apportioned among the seven basin States by two compacts signed in 1922 and 1948. Colorado and the other three Upper Basin States must be permitted to use their respective shares of compact-apportioned Colorado River water.

Of the 17 projects shown in the Summary Volume of the Report, "The Mineral Quality Problem in the Colorado River Basin," six of the proposed projects are within the boundaries of the Colorado River Water Conservation District. Although the Environmental Protection Agency has worked closely with the water resources people in the State of Colorado on a State level, this District would like to suggest that emphasis should be placed by the Environmental Protection Agency on working with the water users themselves. There has been very little water-users knowledge of the preparation of the report and its potential impact upon water users. The right to use water in Colorado and other appropriation States of the Colorado River Basin, under decrees issued by the State Courts, is a property right.

Two irrigation improvement projects listed in Table 8 of the Summary Report are examples: Both of these are within the boundaries of the river District.

Project 2, Grand Valley, Colorado,and Project 6, Uncompahgre, Colorado. It appears that 38,000 and 50,000 acre-feet of water per year, respectively, from these very senior decrees will be left in the river. These waters have been beneficially used in Colorado since around the turn of the century and if they are, in fact, left in the river by various management methods, the owners of the decrees must have the opportunity to participate in the decisions relating to the curtailing of diversions and the disposition of that water. Those users should not be penalized either in water or dollars.

Article II (b) of the Colorado River Compact of 1922 defines the Colorado River Basin as "all of the drainage area of who will be affected. Perhaps the Bureau of Reclamation is the optimum organization to conduct the work of the study.

Much of the land of western Colorado and the western United States of the softer more soluble sedimentary formations contributing to the dissolved solids load by percolation and runoff is owned by the Federal Government.

As an example here, I would like to point out that one tributary of the Colorado River in Mesa County, East Salt Creek, at a sample point which is above all irrigation, and all of the land above this sample point is owned by the United States, is contributing about 11,900 ppm to the Colorado River. The water users must not be penalized in water use or dollar cost because of the salt load contributed by Federal lands.

The EPA study implies the intention to set numerical standards for dissolved solids in various places on the Colorado River. At this time there is not sufficient data to set or to enforce or perhaps even realistically discuss numerical standards. The Colorado River Water Conservation District suggests at this time that the conference not set numerical standards.

Mr. Chairman, that completes my statement.

MR. STEIN: Thank you.

Are there any comments or questions?

MR. O'CONNELL: Yes, I do have one question.

I think your point is certainly well taken that there are many institutional and legal problems that are going to have to be overcome to achieve any degree of improvement of the salinity problem of the Colorado.

One question I had. Reference is made to users with rights to beneficially use water of the Colorado and in situations where improvements in management practices can lead to reduction in water use. Might it be implied from that that the water which is now being used, say, improperly is not being beneficially used in that sense, that amount of water which would be saved by application of proper management practices? I wonder if that question has ever been adjudicated or brought up in Colorado?

MR. FISCHER: The water is being properly used at this time, and the question of what is beneficial use or conversely what is waste has never been decided in Colorado.

MR. STEIN: Mr. Dibble.

MR. DIBBLE: Mr. Chairman, I would like to ask, do you consider that EPA has the legal authority to make that kind of determination?

MR. STEIN: As pointed out, we obviously considered these problems when we entered this situation here, Mr. Fischer. If we didn't have the prior appropriation doctrine and the legal and technical implications of that--I am not just speaking for ourselves--we and the States could have had a much more definitive approach to the water quality problem here.

The very fact that there is a paucity of water quality decisions in your States gives rise to the fact that it has up to this time, at least in the courts, been overshadowed almost completely by adjudication in terms of water quality. But I think we--

MR. DIBBLE: You said "water quality."

MR. STEIN: On water quantity, I am sorry, water quantity.

Now, when we come down to it, here is the basic point. I think if we turn to the California suggestion, we are going to be faced solid with this operation. If we are talking in terms of a net reduction in the amount of salt going in the river we are faced with this: There is going to be additional water there that is probably free of salt if we permit it to stay in the river. Let's suppose say in Colorado that you reduce the salt load 100 tons. If you permit that water to be used downstream after it gets back in the river, over and over again, where the increment of 100 tons is going to be put into it, you haven't saved a bit.

Now, I think you have put your hand on the nub of the problem and what has held us from coming up with a solution up to now. Let us suppose we arrive at the millenium and get the water, as Mr. Kennedy indicated, somewhere below Parker or Imperial Dam down to below 500 ppm of salt. What is the use of doing that if you are going to permit some guy to divert it and run it through and let it percolate through and leach out some stuff and pick up a tremendous salt load and put it back?

In other words, given the prior appropriation doctrine, once we have achieved the salt reduction and we put that water in the stream, how can we under the existing legal patterns keep that water that clean and not permit that to be used by either a lower appropriator or someone downstream to put that salt load back in? Now, I think there is no question of that, that this is the nub of the problem and we are not going to come up with any net gain on this unless we begin to solve it.

Now, when you ask can EPA do this, I don't think so, because, as you know, the law is woven into the constitutional law of the 17 western States. I do recall there are probably one or two old opinions that give you the notion that if you have the right to use water, you don't have the right to pollute it or deplete it in character. Now, I don't want to get into these legal questions here, because the question is if you are going to use it for irrigated agriculture, is the additional salt a pollutant.

I think the laws of the 17 western States--as a matter of fact I am sure they are--are sufficiently flexible that we can require a city or an ordinary industry to put in pollution control devices before they put their water back in the stream. Let's just take this as an example. The point is, though, if we get Denver taking the bacteria, killing the bacteria before they put this waste load in the stream, you are not likely to have a downstream user putting that bacteria right back in within a few miles. The water is going to be pretty clear. And as that water rolls down the South Platte River, we have cleaned it up.

However, if we get the salt out, we don't have that easy a problem. Because, unless we are careful, going downstream someone is going to just make up for that salt load again, and we are going to have a real problem.

This is the crux of our situation, and I think that is why we have to move through this very, very carefully.

MR. FISCHER: Part of your problem with the example of Denver and the South Platte is that when Denver diverts the waters out of the basin of origin it concentrates the salt load in the basin of origin. The situation is one of the big transverters taking the very high quality water out in very large volumes, diverting that water off of igneous metamorphic hard rocks, leaving in the basin of origin for use by the downstream agricultural and other users water that is naturally concentrated in salinity. And there is part of our problem, and this is one of the areas that I think perhaps EPA should take a look at--is not only salt loading but salt concentrate.

MR. STEIN: Oh, I think that was pointed out. I think we thoroughly agree with you on that. We have to work on this, both on the loading and the concentrate, if we are going to manage it in the basin.

But I think again, sir, the key point is this. What can we do once we get water in the stream up to the quality that we would like to maintain, as it rolls downstream past the old diversion points? I am not sure we have a simple answer to that problem. I am not sure that we are going to solve this question of salinity in the Colorado River Basin until we do.

MR. WRIGHT: Could I ask a question?

MR. STEIN: Yes.

MR. WRIGHT: Mr. Fischer, could you describe for me, not in detail but in generalities, the drainage system that your users have in the basin?

MR. FISCHER: Are you talking about the natural drainage basin of the streams?

MR. WRIGHT: No, the irrigation drainage system.

MR. FISCHER: No, Mr. Wright, I can't.

MR. WRIGHT: I see. Well, my reason, of course, for asking was Mr. Boone this morning I think pointed out that better irrigation practices--and one of those practices was good drainage, not allowing the water to percolate deeply into the soil--would help the salinity problems. And you mentioned on page 2 that you didn't believe that your users should be penalized either in terms of water or dollars. It seems like it would not be unreasonable for your users to build a good drainage system if it would decrease the salt load, particularly since Mr. Boone also discussed the possibilities of the Soil Conservation Service funding those investments.

MR. FISCHER: We feel, Mr. Wright, that the users of those No. 1 and No. 2 rights of the Colorado system on the western slope of Colorado should not be penalized in dollars or water. And the reasons are this; that in the appropriation system these people have used this water for many, many years and their livelihoods depend upon it and if they are to be asked to manage that water for purposes other than presently spelled out in Colorado law, they should not be penalized.

MR. STEIN: We understand that position. We would like the States to do that. This is the problem here. And I don't mean to cast any aspersions on this, but we have the same problem, say, that we have in many industries in the East. For example, there are factories up in New England, many factories, that are built right over a stream. That is why the factory was built there. And they have been there since the 1800's, some early 1800's, and they have had to put in pollution control devices because of the increased requirements.

I think this problem is something that we are going to have to face, but I believe you have grasped the crux of the problem, and I am not suggesting that the views you expressed are not almost the universal view I have heard out here. You are suggesting that if you have these people who have had these water rights for a very long time and their whole economy is based on utilizing these water rights and making a living from irrigated agriculture, and if you are going to require them to go to some additional expense--as we required these factories, say, in New England--by putting in tile drainage here, or if you are going to require them to take away some of their water rights and they are not going to use that much water, these people are going to protest. Now, here is the issue.

In other words, Mr. Wright, I think that what we are faced with here is the response we are getting from the people you may say are responsible for the water when it picks up this added salinity. Their response is that if we are going to go ahead with a quality improvement program they don't want to bear the expense.

MR. FISCHER: This is true.

MR. STEIN: Right. All right.

MR. FISCHER: In the East you have a riparian situation where you have got assumptions based on riparian and those assumptions run not only to volume but they run to quality. I think, certainly, that if in appropriation States, and especially Colorado, there is going to be management, either by EPA or through case law, then that management must take into consideration, Mr. Wright, the appropriation doctrine and the priority dates. This is one of the things I said here, if you are going to ask the users in the basin to curtail, I think you have to ask all users of the Colorado River Basin waters as we find in the Compact to also manage for quality reasons and thereby take into consideration the appropriation doctrine.

I notice this with a great deal of interest, that of the seven basin States no State capital is in the basin. Part of our problem of water quality, much of the discussion here today, involves people who are taking that water out of the basin, and therefore I think we must consider that too and we must take into consideration Federal and State law and in Colorado priority dates as decreed by the State courts.

MR. STEIN: I know of two of the cities in those States which are the larger cities in the respective States that are getting a considerable amount of water out of that basin to drink.

MR. FISCHER: They are taking it out to drink, most certainly.

MR. STEIN: Yes, sure.

MR. FISCHER: Right.

MR. STEIN: But let someone else have the capital.

MR. FISCHER: That is true. (Laughter.)

MR. DIBBLE: Mr. Chairman, Mr. Fischer in his last statement implied, if there is a--he said, if I can restate it correctly:

If there is a management program on the management of the waters and if this is dictated by EPA, then certain things should be. He said they ought to take into account the water rights.

I think you were very correct a few minutes ago when you said you were getting down to the crux of the problem because I think you were. And I think the problem is that under the Federal Water Pollution Control Act, EPA and the States are charged in the water quality water pollution control program with control of waste discharges. But I don't read anywhere in that Act where the EPA is given any authority to decide what a person's water rights are, which is a property right, and what they can take from a stream and what they can't take from a stream.

And I think that this conference certainly should make some recognition of that because I don't think there is anything in this law which would allow the EPA in an enforcement procedure to tell somebody they can't take some of the water that a court has already decreed they have or a State has in its procedure.

MR. STEIN: I would agree with you, Mr. Dibble, but here is the problem with that because I think we are right on the verge of that. I am not saying that we would do this, but theoretically we could say," Sure, you can take the water out of the stream, but when you put it back it darned well better be of X quality."

Now, what I think Mr. Fischer has pointed out and several of the other people have pointed out, if we are going to deal with a complex problem like this and not deal on a source-by-source or case-by-case basis of control on that, we may have to, with the States, and hopefully the Bureau of Reclamation, adopt a water management technique which would protect water quality in the stream beds. Because the alternative of that is, as you pointed out before, the problem of the difficulty of enforcing this kind of thing against every individual water user, and I am not sure that that is the way to do it. I think this is the nub of the problem. We are looking for a little different approach to handle this than to put a water quality order against every guy who has a pipe in the stream and a pump and is taking the water in his irrigation.

MR. DIBBLE: Well, in going back to the EPA report on the inter-quality problem, taking the figures off of Figure 45 in Appendix A, I was doing a little calculation to summarize where this salt load comes from in the Colorado River. Taking the river as a whole it is interesting that the natural sources in the net runoff represent two-thirds of the salt, you see, and so when you go to try to do something about this it comes back to the point I was trying to make yesterday,-that it is better to do it as a water resource management technique through a salinity control program because so much of this comes from the natural sources anyway that there isn't anybody to enforce against there. So it is best just to start right out and say this should be a resource management approach to a salinity control program rather than through an enforcement program.

MR. STEIN: That might be. But again you are going to be faced with the problem that Mr. Fischer brought up of the water in the stream. And as I say, and I have no brief with this, but I do think, and I ask you people in the States to think of this, what we are dealing with here is at least a forum, where we have all the States represented and talking it out.

I think at this stage--this is just a personal opinion--there may be more value in keeping this kind of format, than just the approach of either the Federal Government or the States being eliminated from this partnership operation. I suspect that if we take too many steps the other way we will find ourselves in a spot. As I pointed out, you know the history of water litigation as well as I do, and I don't believe that is the way to really try to get at this problem in the foreseeable future.

MR. FISCHER: Right.

MR. STEIN: Thank you very much, Mr. Fischer.

MR. ROZICH: Prior to leaving Denver, the Colorado

Association of Commerce and Industry delivered their statement to me and asked that I enter it as part of the record. Mr. Beverly, who is Director of Environmental Controls for Union Carbide, has agreed to read their statement. And of course, since he didn't take part in preparing the statement, I doubt if he can answer questions on it.

MR. STEIN: I have known Mr. Beverly for years. He can answer a question on any subject. (Laughter.)

ROBERT G. BEVERLY
WATER QUALITY SUBCOMMITTEE
OF THE ENVIRONMENTAL QUALITY COMMITTEE
OF THE COLORADO ASSOCIATION OF COMMERCE AND INDUSTRY
GRAND JUNCTION, COLORADO

MR. BEVERLY: I am Robert Beverly and I am interested in the conference. I think I have attended every session that the conference has had. And I am on the Water Quality Subcommittee of the Environmental Quality Committee of the Colorado Association of Commerce and Industry.

This statement is made in behalf of the Colorado Association of Commerce and Industry, an association of more than 900 Colorado businesses, and is being made for the obvious reason that the future of the waters of the Colorado River is of extreme importance to them as it is to all citizens of Colorado and of the entire river basin.

We recognize that man exerts a powerful influence on the environment. The process of making and operating the host of things demanded by our society has been accompanied by necessary and unnecessary effects on the environment. Acknowledging that man has the responsibility and obligation to avoid unnecessary, and to minimize necessary, disruptive impacts on the environment, it is appropriate to implement all possible means to achieve goals of environmental quality that best serve the public interest.

Among the resources of concern to ensuring an acceptable quality of life is the quality and quantity of our water resource. Many of our waters, such as the Colorado River, must be used and repeatedly reused to service the many present and future beneficial uses. The imposition of water quality standards, such as salinity, should reflect an appropriate determination of attainability with full regard to the inventory of natural and manmade contributions to the salinity within the river system. This would take into account the degree of water quality enhancement achievable from the application of good conservation, treatment and watershed practices.

We recommend that prior to the adoption of any numerical salinity standards salinity studies should be undertaken to identify and inventory each and every source throughout the river system, including tributaries, from natural and man-made sources. Furthermore, in the necessary over-all study of salinity problems of the Colorado River, economic benefits must be analyzed and correlated with the analysis of economic detriments. We note the comment of the State of California, Appendix D, that, "the report makes no mention of the precedent-setting work on salinity control programs in the Arkansas and Red River Basins in Texas and Oklahoma." We suggest that any study and proposed program must consider data developed by these studies on control of natural resources of salinity.

It must be recognized that other factors, such as a permit program under the 1899 Refuse Act or proposed changes in Federal water quality legislation, may significantly reduce, by imposition of effluent controls, many sources of salinity. The Environmental Protection Agency sponsored Pacific Ocean desalinization projects could also have a significant effect upon the salinity problem.

The United States recognizes through its study, "The Mineral Quality Problem in the Colorado River Basin," that the quality of the water within the Colorado River Basin is a matter of interstate and international concern. Therefore, in order to achieve the desired goals and to accomplish the desired results, adequate Federal funds snould be made available to insure the development of a practical logical program and its success. Costs will be significant in achieving any controls to either manmade or natural sources of salinity.

Any program and implementation plan which is to be adopted must be developed and agreed upon by all the States of the Colorado River Basin as well as the interested Federal agencies and existing river authorities.

This is respectfully submitted under the name of Raymond A. Kimball, the President of the Colorado Association of Commerce and Industry, and statements were delivered to Governor Love and the Colorado Congressional Delegation.

I would like to add just a couple, three comments of my own.

We recognize that an inventory--I mentioned a thorough inventory should be made. We recognize an inventory has been made. We think this should be updated, and more important, I think we should have an evaluation of the technical and economic feasibility of reducing the salinity from these point sources.

I also was looking, as Mr. Dibble was, through the report. I note that 1 percent--that is about what the paper said this morning--1 percent was from municipality and industrial sources on the Colorado River. These may or may not lend themselves to enforcement action, but how do you enforce reduction in the 33 percent of the agriculture usage? Sure, we have some ideas, but I think they are really not reduced to complete practice at this time, but I am not knowledgeable on that, I won't speak to that. But more important, how do we reduce 65 percent of the salinities from natural sources?

If anybody comes up with the answer to Blue Springs, I am sure industry throughout the country will be most interested because salinity is a problem countrywide to remove it from large quantities of water. So if the Blue Springs answer comes out, I would say it would certainly be useful.

Since radium in water has been alluded to a number of times, I would mention I think it is a good example in reverse here. Something over 90 percent of the radium that was ever coming down the Colorado River was coming from natural sources. We had a few problems in local mills and these were corrected. We appreciate all the compliments on the job done. But we wouldn't know today how to remove that 90 percent that was coming from natural sources. And I think this is the case with salinity.

And I think we all agree with the goals, as Mr. Dibble and Mr. Williamson have referred to, as far as enforcement action. We have to find some technical answers before we can really expect any significant reductions in salinity.

I am ready to go to lunch and so are you.

MR. STEIN: Are there any comments?

If not, thank you very much.

We will stand recessed for lunch. And let's be back by 1:40.

(Whereupon, at 12:10 o'clock a noon recess was taken.)

AFTERNOON SESSION

WEDNESDAY, FEBRUARY 16, 1972

1:40 o'clock

MR. STEIN: Let's reconvene.

Mr. Rozich.

MR. ROZICH: Next I have a statement that came the long way getting to me. It is a statement by Mr. Lloyd Summerville, who is with the Colorado Farm Bureau. It was delivered to me this morning by Mr. Leonard Johnson, Assistant Director, Natural Resources Department, American Farm Bureau Federation, and he asked that I read it, so you will have to bear with me. I am not familiar with his style of writing, so it may not sound too well.

> My name is Lloyd Summerville of Fruita, Colorado, President of the Colorado Farm Bureau, which is a general farm organization of 13,235 members in the State of Colorado.
>
> Colorado Farm Bureau appreciates this opportunity of presenting its members' views relative to the problems of salinity of the Colorado River waters. Farm Bureau's approach to establishing environmental quality standards is found in its basic policies relative to quality of the environment. These policies state:

We pledge cooperation with all responsible groups in cleaning up pollution of the environment. We urge that pollution regulations be based upon researched facts and that they provide a reasonable period of time for abatement of pollution.

Farm Bureau members have expressed concern for some time over the salinity buildup on the Colorado River. We supported the establishment of water quality standards for States and rivers. In accordance with our policy, we supported and recommended that studies be completed to clearly identify the sources of salinity pollution of the Colorado River. We recognized that much work has been accomplished by the Bureau of Reclamation and the States in pollution studies of the river. From these pollution studies a salinity control plan is being developed by the conference States. We think a control plan should be provided opportunity to be implemented.

We believe the establishment of a numerical salinity standard for the Colorado River at any of its key check points would be unwise at this time. Such an approach would divert attention away from abatement plans for natural salinity sources and could place emphasis upon salinity resulting from use and development of the river's resources.

An essential part of a healthful environment is the wise and balanced conservation of resources. Some conservationists appear to misinterpret the full significance of the word "conservation."

President Theodore Roosevelt had engraved beside his bronze statue in Washington, D. C., these words, "Conservation means development as much as it does protection."

The sound conservationist understands, as Teddy Roosevelt did, that there is a mutual relationship between man and nature, that man must serve nature so that nature may serve and support man.

We believe there should be a clear distinction between natural salinity sources and salinity due to development and use. From such a base of facts there can be a comprehensive, balanced program of healthful development on sound conservation and environmental principles in the Colorado Basin.

We believe the States have already made progress towards implementation of a salinity control program on this river without a firm numerical standard. At the same time, we recognize there is much more that needs to be done.

If there is need to strengthen the existing salinity control program, including adequate funding by Congress, we support improvement of the program plus an aggressive funding plan.

We appreciate the opportunity of making this statement and restate our commitment of cooperation with those who seek to improve the quality of the environment. We ask that abatement plans be based upon soundly researched principles and that a reasonable period of time be programmed for corrective measures.

MR. STEIN: Thank you.

Any comments or questions?

I suggest one typographical change. I know that you didn't do this, but a lot of people read this and notice the language. Check page 2. After Theodore Roosevelt that should be "has" instead of "had." O. K.? The way this reads is,

> President Theodore Roosevelt had engraved beside his bronze statue in Washington these words, "Conservation means development as much as it does protection."

I think obviously it should be "has."

MR. ROZICH: Right.

MR. STEIN: O. K. It will save us a lot of trouble. Thanks.

Any comments or questions?

Mr. Rozich, any more from Colorado?

MR. ROZICH: I have a statement here that is a joint statement of the Colorado Water Conservation Board and the Colorado Water Pollution Control Commission, and Mr. Morrill, who is listed as being our first speaker, begged off, and now he would like on following my statement, and his will be only a short statement.

FRANK ROZICH, DIRECTOR
WATER POLLUTION CONTROL DIVISION
COLORADO DEPARTMENT OF HEALTH
DENVER, COLORADO

MR. ROZICH: As an agency vitally interested in the prevention and abatement of pollution and as an agency attempting to enhance all waters of the State, we endorse the philosophy and concept of salinity control in the Colorado River Basin. The adoption of broad water quality objectives to maintain salinity concentrations at or below present levels in the Lower Colorado River Basin is an objective which both Upper and Lower Basin States should carefully consider. The details proposed to accomplish this objective leave many important questions unanswered. The legal, institutional and political considerations, as well as the equity considerations, have not been fully explored and a satisfactory solution to these factors will certainly be needed before the details of the salt load reduction program can be fully implemented.

As was noted in the comments of all of the States with regard to the draft report of last year, all were against the adoption of numerical criteria at this time. We concur that the adoption of numerical criteria should be deferred until the potential effectiveness of Colorado River salinity control projects are better known. It should also be noted that when enough information is available to possibly set such numerical criteria, means must be provided to equalize the information gathered in both the Upper and Lower Basin States. By this I mean that in the Lower Basin States at Hoover and Imperial Dams the existence of these large storage reservoirs serves to provide mixing of dissolved solids in the water. As a result of this mixing effect, the salinity concentrations below these reservoirs are not dependent on flow and the maximum mean monthly salinity concentration tends to stabilize throughout the year regardless of flow of discharge. This is not true in the Upper Basin States as concentrations will vary inversely with the flow.

Colorado feels that the construction of salinity control works, along with the full development of water resources in both the Upper and Lower Basin States, should continue. However, in reading the reports, it isn't too clear as to who will be assessed the cost of such salinity control projects. Fifteen of the 17 projects mentioned in the report are located in the Upper Basin States. Of the 15 Upper Basin projects, seven would be in Colorado. Of the seven projects in Colorado, five are labeled as irrigation improvement projects. These projects would have an average annual cost of a little over $13 million. Only approximately $6.5 million has been assigned to salinity control costs, the assumption being that the other $6.5 million would be returned to the water users and the irrigators in the form of improved crop yields. Although this report mentions local costs in a very general way, the draft report of November 1970 indicates that at least $6.5 million would be paid by local investment. This figure would run even higher if any of the salinity control projects were assigned to the irrigators.

The above figures are all based on 1970 dollars. It is well to remember that only that portion assigned to salinity control costs is used in the benefits to cost ratio and other projected dollar values used in this report. It is also well to remember that 80 percent of the benefits accrue to the Lower Basin States. It is therefore recommended that congressional authorization and funding be sought for the purposes of reconnaissance and feasibility studies for the entire river basin. Unless such Federal moneys are provided for a basinwide salt load reduction program, it could place an intolerable financial burden on individuals and/or State governments. I am informed by our Department of Agriculture that the average income of the farmer or irrigator in the Colorado River Basin in Colorado is a little over $4,000 per year. Therefore, it is easy to see that such a group of irrigators could not afford an expenditure of approximately $6.5 million a year.

It is our understanding--and after yesterday's talk by Commissioner Armstrong it is more than an understanding now (laughter)--that the Bureau of Reclamation has been authorized to make and has feasibility investigations under way with regard to determining further means of reducing the salinity of the Colorado River. We, therefore, feel that the conferees and EPA should support the Bureau of Reclamation in these efforts. In order to advise and guide the Bureau of Reclamation with respect to these investigations and research plans, Colorado would be receptive to setting up some sort of a task group which would include other disciplines in addition to water pollution control people. However, our State Water Pollution Control Commission does not at this time feel that they wish to relinquish their authority within Colorado to any river basin commission or State-Federal agency that would have the powers to carry out all phases of activities necessary to basinwide management and control of salinity.

In conclusion, we feel that much has been done in the past few years to control salinity pollution within the basin, and on the other hand, much remains to be done. We, therefore, have come to this conference with an open mind towards understanding the positions of the other conferees and EPA and hope that we will all leave this conference with the feeling that constructive actions have and will continue to be taken in the control of salinity without impeding development in any of the States.

Thank you.

MR. STEIN: Thank you, Mr. Rozich.

You know, there is one important point. I am not sure, maybe the Department of the Interior people can tell me. You are not authorized yet to go ahead with these salinity studies, are you?

MR. MALETIC: Yes, we are.

MR. STEIN: You are?

MR. MALETIC: Indeed. The three acts that were cited in Commissioner Armstrong's statement--

MR. STEIN: I know, but under the general acts. In other words, you feel that the general acts give you authorization?

MR. MALETIC: Give us that authority and we have the program funded and moving.

MR. STEIN: Right. All right, thank you.

Are there any comments or questions?

MR. TABOR: Just a geographical correction on the first page, "... at Hoover and Imperial Dams the existence of these large storage reservoirs..." Imperial Dam is not a storage reservoir.

MR. ROZICH: I think I was referring to the reservoir behind the dam rather than whether it was storage or otherwise. In other words, what I was trying to point out is that here you have a mixing basin. And whenever you collect samples for TDS there is not going to be too much fluctuation, whereas in the Upper Basin States, at least at present, when you are collecting it out of the river, it is going to fluctuate with the flow and many times there is quite a fluctuation.

MR. TABOR: Thank you.

MR. STEIN: Any other comments or questions?

Does that complete Colorado, Mr. Rozich?

MR. ROZICH: Except for Mr. Morrill. He wishes to make a very short statement.

Mr. Morrill is Deputy Director of our Water Conservation Board.

L. D. MORRILL
DEPUTY DIRECTOR
COLORADO WATER CONSERVATION BOARD
DENVER, COLORADO

MR. MORRILL: My name is L. D. Morrill. I am Deputy Director of the Colorado Water Conservation Board and I would like to make a very brief statement on a point mentioned by Mr. Fischer.

He stated that irrigators with old decrees should not be penalized in water or dollars through the imposition of salinity control measures. It is a statement with which I agree.

For the past several years the State of Colorado through the Water Conservation Board, in cooperation with the Colorado State University, the Soil Conservation Service, the Bureau of Reclamation, and EPA have carried on studies in the Grand Valley, which is near Grand Junction, of the costs of improving irrigation and drainage practices with the objective of decreasing the salinity of the Colorado River. While such studies are not complete, early indications are that the irrigators may actually benefit financially from such improved practices because of increased crop production.

One of the things that Colorado would like to see would be a large-scale demonstration project in the Grand Valley to find out if the indications of the present small-scale studies are correct, and we recommend that the EPA help us initiate such a project.

I think that is my statement.

MR. STEIN: Thank you.

Any comments or questions?

If not, thank you very much.

MR. ROZICH: Is Mary--I can't pronounce the name--Kozlowski here? I understand she has a statement to make on behalf of the Rocky Mountain Center on Environment. And I didn't know whether it should be included under the Colorado portion or under the Nevada portion since I understand you are from Nevada.

MR. WESTERGARD: Yes, we claim her.

MARY KOZLOWSKI
NEVADA OPEN SPACES COUNCIL
LAS VEGAS, NEVADA

MS. KOZLOWSKI: Thank you. I am glad you do. I would hate to be without a country.

But I also have a statement here that I received this morning from three Colorado organizations.

MR. STEIN: Pardon me. I don't think you understood the ground rules. I know Mr. Westergard has the syllables tripping off his tongue, but would you give us your name and how you spell it, please.

MS. KOZLOWSKI: Oh, O. K.

It is Mary K-o-z-l-o-w-s-k-i.

Now do you want to decide whether I should give this statement during the Colorado portion?

MR. STEIN: Oh, no one is going to tell you to go away. (Laughter.)

MS. KOZLOWSKI: Several organizations have sent me their statements with the specific request that they be read into the record. I will be reading their statements for them in their absence, and as a reader I feel that I cannot give interpretations or answer questions concerning the comments that they have put in their statements. They were given to me this morning air mail special delivery, and so I would continue on this basis if it is acceptable to you.

MR. STEIN: Go right ahead.

MS. KOZLOWSKI: The first comments will be made by the Eagle Piney Water Protection Association, Colorado Open

Space Council, and Trout Unlimited-Colorado Council. This is their statement for the Colorado River enforcement conference.

Gentlemen:

The following is our statement of position concerning the mineral quality problem of the Colorado River Basin. We have asked Mary Kozlowski of the Nevada Colorado River Commission to present this statement for us personally at the enforcement conference in Las Vegas. Eagle Piney Water Protection Association is a newly-formed State group which represents several hundred individuals and assorted conservation-water State organizations concerned with State water problems. Colorado Open Space Council is a Denver-based organization representing 47 separate conservation organizations throughout the State of Colorado. Trout Unlimited-Colorado Council represents approximately 1,000 members in Colorado and is an affiliate of Colorado Open Space Council and Eagle Piney Water Protection Association.

1. The adverse effects of transmountain water diversions.

As the Environmental Protection Agency Summary Report on the Mineral Quality Problem on the Colorado River Basin aptly states, "Out-of-basin diversions from the Upper Basins contribute significantly to stream flow depletions and produce a salt concentrating effect similar to consumptive use."

The Environmental Protection Agency should be advised that on the Upper Colorado River there are numerous transmountain diversion projects under consideration, new ones and enlargements of existing projects, which, if permitted to proceed, will seriously further deplete the stream flow of the Colorado River to an enormous extent (perhaps in the neighborhood of 1 million acre-feet a year). Some of these planned new and enlarged transmountain diversion projects are:

(a) The Windy Gap Project on the Upper Colorado River mainstem near Hot Sulphur Springs-Six Cities Users' Association (subdistrict of Northern Colorado Water Conservancy District).

(b) The Eagle Piney Project and the Eagle Colorado Collection System on the Eagle River and its tributaries, Piney River and its tributaries, the Colorado River and its tributaries, and the tributaries of the Blue River (below Dillon Dam) - The Board of Water Commissioners of the City and County of Denver.

(c) Homestake Project on Homestake Creek and Cross Creek and their tributaries (all tributary to the Eagle River) - Cities of Colorado Springs and Aurora.

(d) Twin Lakes Canal and Reservoir Co. on the Roaring Fork River above Aspen, Colorado - (private corporation).

(e) Fryingpan-Arkansas Project on the Fryingpan River (tributary to the Roaring Fork River at Basalt, Colorado).

(f) The Central-Colorado-Denver Project of the Central Colorado Water Conservancy District

(g) San Juan-Chama Diversion Project on the Blanco and Navajo Rivers near Pagosa Springs- Bureau of Reclamation.

(k) The Gunnison River claims of the

Central Colorado Water Conservancy District and Messrs. Oxley and Bunger (both sets of claims representing a reincarnation of the old Bureau of Reclamation Gunnison-Arkansas Project).

We urge the Environmental Protection Agency to consider declaring that a state of emergency exists as to the quality and quantity of water in the Colorado River Basin in light of these new developments and enact a moratorium on transmountain diversions of water in connection with new projects yet to be built and proposed enlargements of existing projects. The moratorium should be set up to last until the Federal Government and its associates have a chance to study all of the pertinent ramifications of these proposed diversions on the quality and quantity of Colorado River water.

2. Water Quality and Quantity Control and Existing Legal Constraints.

Colorado laws concerning water rights appropriations and beneficial use of water do not presently countenance water quality or quantity control, both of which are required to save the Colorado River Basin from becoming more seriously depleted and polluted as a result of the maximization of water development projects planned for the near future.

We urge the Environmental Protection Agency to assist on-going Colorado Statewide efforts to obtain legal protection for streams and river basins of origin and to bring about changes in Colorado water laws so that water quality and environmental protection purposes (among others) will be considered valid beneficial in-stream uses of water, capable of appropriation, in the State of Colorado.

We ask that these recommendations be placed in the official record of your proceedings.

I also have a statement from the Rocky Mountain Center on Environment.

The Rocky Mountain Center on Environment (ROMCOE) has reviewed the report on "The Mineral Quality Problem in the Colorado River Basin" of 1971, and appreciates the opportunity to submit these comments for inclusion in the conference proceedings.

ROMCOE is a private, non-profit regional environmental service center, providing a broad range of environmental assistance to government, conservation groups, industry and the general public in the eight Rocky Mountain States. These comments are prepared by the ROMCOE staff and do not necessarily represent a formal position of the ROMCOE Board of Directors.

ROMCOE has recognized and been concerned about Colorado River Basin salinity for several years. The extremely rapid multiplication of the salt load in this century is another example of a stress on the ecosystem resulting from man's abuse of the principles of ecology. The basic cause of this stress is the exceeding of "carrying capacity" of the land. The efforts to manipulate natural processes, to extract more resources and biological production than the region can support within naturally-created limits is causing the collapse of an element of the ecosystem. Man in the Rocky Mountain West must learn to live within the capabilities of natural systems.

The logic of the water development syndrome, which is the first cause of the salinity problem, goes like this:

(1) Economic growth, development and population growth are vital to the future of the West.

(2) Economic growth and development depend almost entirely on development and redistribution of water supply.

(3) Increased water supply will require considerable accelerated water development and redistribution projects.

(4) Water development and redistribution will assure ever-expanding economic growth and population expansion.

(5) Expanding populations and economic growth will generate new demands for increasing water development and redistribution projects.

(6) Return to Step 1.

Manifestations of other root causes of the salinity problem are: Western water law; the false alchemy of turning land into money by liberal sprinklings of water; and accelerating growth ethic pressures for more water-related "pork barrel" projects.

Western water law evolved at relatively the same time and under the same frontier circumstances as the Mining Act of 1872. Both are in need of drastic revision. It is imperative that Western States recognize water quality control and ecological processes, as well as recreation, fish and wildlife and aesthetics, as "beneficial uses" of water resources. It is essential that priorities of appropriated uses be restructured to balance beneficial uses. It is to EPA's credit that this issue is identified in the report; Western States can no longer duck the question.

Current water wisdom and water law generate exploding developments that turn "land into money." The massive water projects which stimulate rapid and uncontrolled growth, to the primary benefit of a small number of people and to the detriment of the general public, are not predicated upon sound principles of land use.

And the creation of new land use patterns is the ultimate result of the projects. It is time to relate planning and development of water resources to proper land use planning. Federal money should no longer be used to perpetuate past mistakes which fail to recognize the inextricable relationships between water resources development and land use decisions.

Water policy which has caused the TDS problem of the Colorado Basin needs to be reexamined in a whole new perspective. Projects have been developed without a true assessment of total social costs and total social benefits. Resulting salinity is but one "disbenefit" which has been ignored in the accounting system for project justification.

In specific response to the report, we would suggest a number of actions:

(1) There should be a moratorium, perhaps permanent, on any Federal assistance or approval of diversions out of the Basin. Federal money or authorization should not be involved in any project which is part of a system

resulting in such diversion. The projects mentioned in the report are not a complete listing; for example, the Bureau of Reclamation is planning diversions from the Green to the Missouri Basin in Wyoming and Montana. The EPA Report discusses the fact that these are high-quality headwaters which will be diverted, reducing Colorado River flows but not salt loads by an equivalent amount. Additionally, most of these projects involve reservoirs, which increase evaporation losses (although such losses are small compared to Lake Mead and Lake Powell). Interbasin transfer economics often are not favorable when subject to close scrutiny, as is indicated by a recent book by Howe and Easter.

(2) An Interstate Commission should be created to address the salinity problem comprehensively. This Commission should be a State-Federal partnership. If left to their own devices, the States individually will probably never resolve the problems and achieve the necessary results in salinity control. The history of water quality control to date substantiates this thesis.

Proposals for lining irrigation ditches, "flushing" salt-laden streams and building desalinization plants are piece-meal approaches that avoid the basic issues.

In fact, we are dismayed by the discussion of several of the alternatives to reduce the salinity problem. We cannot condone, at this point, any approach which perpetuates the present philosophy of treating the symptoms rather than the disease. The approach of out-basin diversions, augmentation into the basin, more storage and evaporation, and salinity control and removal may well become a technological-economic treadmill.

(3) Numerical criteria should be established. It is recognized that additional research is needed, but this should be conducted as rapidly as possible. Again, the absence of numerical standards historically has resulted in an absence of pollution control in America.

Additional new and innovative approaches should be investigated. A discharge permit program for irrigation runoff might be established. To overcome the problem of over-irrigation because of the fear of losing water rights, the Federal Government might acquire water rights in lieu of irrigation water payments. Such rights could then be used for the beneficial uses of quality control (although such rights might be downstream of the areas where the maximum need for ecological beneficial uses occurs).

New methods of controlling and delivering irrigation water, such as those used in Israel, should be implemented. (Water can be metered and piped to plant roots, using water with TDS concentrations of 1,000 to 2,000 ppm, apparently based on Israeli experience.) Federal monies might better be spent on approaches such as this rather than a continuation of the "conventional wisdom" methods.

ROMCOE believes that the National Environmental Policy Act's phraseology about wise stewardship and future generations must be taken seriously. Any program which does not have specific elements for control of excessive consumption must be reexamined. Any program which does not demonstrate definite means for conservation of resources is deficient. Western water use, both agricultural and municipal, at present does not conform to the intent of NEPA.

Most certainly, as mentioned in the Report, land suitability should be a major factor in assessing federally-funded projects. Irrigation of lands of high salinity or marginal agricultural productivity should not be permitted. Similarly, federally-assisted water projects for municipal and industrial use should recognize the erosion and salinity suitabilities of land proposed for development. Even though the total municipal contribution of salt load to the Colorado River is low, it is more readily susceptible to control than many natural sources.

Additional funding for research and control is in order. It is indicative of the root cause of the problem that the Bureau of Reclamation has a higher-than-usual budget for project development, which will aggravate the water quality problem. A reallocation of funds from development to research and control is in order.

The study should identify future consumptive losses more accurately. Massive thermal powerplants and oil shale development (with 1-1/2 to 3 barrels of water consumed per barrel of oil produced) will have significant effects.

The study should identify secondary impacts more carefully. If removal of salt from irrigated land is accomplished by flushing, additional fertilizer must be applied. This will cause a higher nitrate level in both surface and ground waters, with potential adverse effects such as lake eutrophication and methemoglobinemia. This is but one example of a potential secondary disbenefit.

The incidence of costs of salinity might be more precisely described. The report states that the cost incidence of salinity is largely assignable to farmers. Yet the August 1970 report by the Colorado River Board of California states that water users are continuing to make large investments in drainage facilities to maintain productivity. The costs are passed on to the consumers. The cost incidence may therefore be assignable to a broader segment of society, including low-income people to whom increased food prices are a major burden.

In institutional matters, a positive program for public participation should be identified. This conference is but one form of participation; other types should be utilized as well.

It is noted that the study used a 5 percent discount rate in determining present worth of investments in salinity reduction programs. If a more realistic 10 percent "opportunity cost" were used as the discount rate, the investments would be much higher in present worth. This argues against the high-investment technological control alternatives and in favor of the alternative of "limited development." The latter alternative is also an appropriate approach as regards numerical criteria for salinity because the salinity vs. time curve flattens and becomes constant. Also, it conforms most closely to the use of ecological principles in planning.

The Report states that this "limited development" alternative may cause benefits to be foregone.. In some cases this may be true. However, because past benefit/cost ratios have not assessed total costs, the "benefits foregone" may well be "disbenefits foregone" in many cases. The use of a more realistic discount ratio will yield lower net dollar benefits; many past projects have been funded on the basis of an artificially low discount rate.

The alternative of limited development would reduce the difficulty of the control cost allocation question, where Upper Basin States contribute the salinity but Lower Basin States suffer the costs.

Some of the methods contemplated for control of natural diffuse sources will start another round of technological bandaids. Sealing of ground surfaces, contour ditches to pick up runoff and carry it rapidly to streams and similar methods will be quick-fixes, the secondary result of which will be disbenefits in a broad range of categories. The study team should proceed farther in identifying these secondary impacts and effects.

Alternatives involving desalinization which requires electrical power (such as distillation or electrodialysis) should be discouraged.

The Report discusses out-basin diversions in terms of helping the Colorado River quality problem. These diversions should be viewed in another way: the Colorado River salinity problem diminishes the merits of further out-basin diversions.

In summary, ROMCOE finds much to praise in the EPA Report and work. Its conclusions and recommendations merit support. ROMCOE is directly involved with only eight Rocky Mountain States, not including California. However, parochialism or regional chauvinism have no place in the problems addressed by the Report. The ecosystem knows no political boundaries. Mexico and America are not separable in terms of ecological processes, and the problem of salinity must be considered in this frame of reference.

Thank you very much.

MR. STEIN: Thank you.

Any comments or questions?

MR. ROZICH: I would just like to apologize for someone with a name like Rozich not being able to pronounce Kozlowski. (Laughter.)

MR. STEIN: I will bet it took you years before you could pronounce Rozich. (Laughter.)

MR. WILLIAMSON: I would like to make a comment on this matter of diversion, maybe.

I think it is probably the 10 years of experience that some of us have had sitting on this thing that we remember the ground rules and maybe the people who have only got involved in this in the last few years don't know what ground rules were laid down to start with, and I think this is probably important.

It was a common agreement when we started that in no way would water quality standards or such ever be used to circumvent the allocation of waters as laid out in the Compact.

Second, that in no way would we infringe on a State's right to use their allocated share of water. This matter of diversion is a State-controlled thing. If you are unhappy with the diversions in your own State, then do something about your

State law. These are the ones that are controlled by the State.

So I don't think for the conferees here to sit here, and me,to tell Colorado they can't divert water, Colorado tell us we can't divert water, this is our own problem to solve and I don't think it is a fittin' problem for the conferees.

This matter of ecology words jumped up here. We have run into it before. A number of us have been in the ecology business for 30 years, anyway. And it always comes to my basic first thought, speaking of ecological systems, remember Barry Commoner's basic law of ecology and that is, "There is no such thing as a free lunch." Whenever mankind is going to exist on this earth he is going to pay one end or the other. It makes no difference if we want it for the fish, the wildlife, and so forth, we are going to pay for it in reduced food and fiber on the other end, high prices of putting some better land under cultivation somewhere else.

So just to say we are forgetting the ecology on one end--maybe. We have got to look at the other end also on the thing because somebody will pay in the end.

That is just a comment I had to get in. Thank you.

MR. STEIN: Any other comments or questions?

Thank you, Mr. Williamson. You know, we are just here to improve the quality of waters and I suggest that some of the comments may be directed toward changing the world. However, if I were going to change the world, Mrs. Kozlowski, there is no one whose spirit I would enjoy more than yours.

We are going out of order just slightly because we have a request here for someone to appear before 2:30.

Is Charles Wilkinson of the Native American Rights Fund here?

CHARLES F. WILKINSON
NATIVE AMERICAN RIGHTS FUND
BOULDER, COLORADO

MR. WILKINSON: Mr. Chairman, I very much appreciate your calling me out of order and I will be quite brief.

I might mention that our statement does have attached a fairly long exhibit which will not be read into the record.

My name is Charles Wilkinson from the Native American Rights Fund in Boulder, Colorado. We represent American Indians. Mr. DeFalco of Region IX was kind enough to ask Joseph Brecher of our office to appear today and he is unable to testify and so I will appear in his behalf. He regrets his inability to come.

The continued existence of the five Lower Colorado

Indian tribes, the Chemehuevi, Cocopah, Colorado River, Fort Mohave, and Fort Yuma, is entirely dependent on water from the Colorado River. The Supreme Court has recognized an obvious fact: the survival of the Lower Colorado River Indian tribes depends on an adequate supply of high quality water. They have no other source of water supply than the Colorado River.

In 1964, the United States Supreme Court ruled that these five tribes were entitled to 905,000 acre-feet of Colorado River water, Arizona v. California. The Supreme Court explained its action in an earlier opinion as follows:

> Most of the land in these reservations is and always has been arid. If the water necessary to sustain life is to be had, it must come from the Colorado River and its tributaries.

Congress and the President knew when they created the reservations that:

> Most of the lands were of the desert kind--hot, scorching sands--and that the water from the river would be essential to the life of the Indian people and to the animals they hunted and the crops they raised.

The water was to be used "to irrigate all practicably irrigable acreage on the reservations." Again that is a quote from Arizona against California. In view of this total dependence, the Environmental Protection Agency's Summary Report on the Mineral Quality Problem in the Colorado River Basin presents a reason for great apprehension. The report notes that in the lower Colorado River, salt concentrations already exceed threshold limits for municipal, industrial, and agricultural uses. The effect has been a reduction in crop yields and in the types of crops which can be successfully grown, as well as a deterioration in soil quality.

As bad as the situation is today, the Summary Report predicts that it will get much worse if current water diversion plans are allowed to continue. Eighty percent of the predicted future increases in salinity can be attributed to such diversions.

By far the most significant of these diversions will be the Central Arizona Project, authorized by the Colorado River Basin Project Act. The Bureau of Reclamation has estimated that the CAP will divert 1,650,000 acre-feet of Colorado River annually at Lake Havasu. There are numerous other Colorado River diversion and storage projects in the Upper Basin authorized by Congress. They, too, will have a major effect on downstream salinity.

C. F. Wilkinson

The effect of this major flow depletion in terms of downstream salinity has never been studied. In the Bureau of Reclamation's Draft of Environmental Statement for the Central Arizona Project, prepared under the mandate of the National Environmental Policy Act, the only mention of the salinity problem occurs on page 37, where it is stated as follows:

> The impact on water quality of the Colorado River main stem below Parker Dam from diversions of water for the Central Arizona Project will not be significant. Operating criteria for the river with the Central Arizona Project on line will reduce the possibility of surplus flows in the river below Parker Dam. While surplus flows would provide some incidental dilution in the river below Parker Dam, their infrequent and unreliable occurrence minimizes their value. The last significant surplus flow occurred in 1963.

It can thus be seen that the Draft Environmental Impact for the CAP totally ignores the critical problem of increasing salinity. Under Section 309 of the Clean Air Act, the Administrator of the EPA is required to review and comment in writing on the environmental impact of Federal projects such as the CAP. Senator Muskie, the sponsor of the Clean Air Amendments of 1971, which added Section 309, stated to Mr. Ruckelshaus during the hearings on Mr. Ruckelshaus's nomination, that 309:

> ...makes you a self-starter, whenever you, unilaterally, see the environmental risk. What is involved here is not an input to somebody else's decision and somebody else's statement. This is an issue to be taken by you.

Ending the quote from Senator Muskie.

The draft Environmental Statement for the Central Arizona Project contains numerous other serious deficiencies. A detailed discussion of these defects is contained in a document we submitted to the Bureau of Reclamation on November 10, 1971. A copy of that comment is attached to this testimony as Exhibit A.

Pursuant to its obligation under the Clean Air Act, we believe that the Environmental Protection Agency should make a definitive study of the environmental effects of the Central Arizona Project, with a special emphasis on the salinity problem. The results of this study should be incorporated in EPA's comments on the Central Arizona Project and, if modifications to eliminate these problems are not forthcoming, EPA should implement Section 309(b) of the Clean Air Act by publishing a determination that the Project is unsatisfactory from the standpoint of environmental quality and should refer the matter to the Council on Environmental Quality.

(Exhibit A referred to follows:)

Native American Rights Fund

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EXHIBIT A /

10 November 1971

Mr. E. A. Lundberg
Regional Director
Bureau of Reclamation
Regional Office - Region 3
P. O. Box 427
Boulder City, Nevada 89005

Dear Mr. Lundberg:

The following comments on the Draft Environmental Statement: Central Arizona Project are submitted on behalf of the Chemehuevi Tribe of Indians and the Natural Resources Defense Council. The Supreme Court, in Arizona v. California, 376 U.S. 340, awarded the Chemehuevi Tribe 11,340 acre feet of Colorado River water. The Chemehuevi Tribe believes that construction of the Central Arizona Project will threaten the quality and quantity of Colorado River water available to them and that the adverse environmental impacts associated with that construction will affect their health, welfare, and livelihood.

The data presented in the draft statement is totally inadequate. As the court said in Environmental Defense Fund v. Corps of Engineers, 325 F.Supp. 725, 759, an impact statement must "contain such information as will alert the President, the Council on Environmental Quality, the public, and indeed the Congress, to all known possible environmental consequences of proposed agency action." The Council on Environmental Quality's Guidelines for federal agencies under the National Environmental Policy Act, 36 F. Reg. 7724, et seq., paragraph 6(a)(i), says a draft statement must include "a description of the proposed action including information and technical data adequate to permit a careful assessment of environmental impact by commenting agencies." Also, under paragraph 10(e) of the Guidelines, the public must be provided with "relevant information, including information on alternative courses of action." Obviously, the public is not "informed" at all, when relevant data is missing from the statement. Almost every page of the draft statement contains admissions that data is lacking, that information is "unknown," or that tests are presently being conducted, the results to be determined in the future.

Another basic flaw in the draft statement is the unchallenged acceptance of the proposition that growth must continue unabated in Phoenix and Tucson and that it is the duty of the government to supply the wherewithal for that continued growth. The Council on Environmental Quality has recognized that "population growth threatens the nation's store of natural resources" and that in some rapidly growing areas, "there was now a need to de-emphasize growth as a social goal . . ."[1] Instead of invoking the need for growth in Phoenix and Tucson as an imperitive reason to build the C.A.P., the statement should have been considering seriously the possibility that such growth is a reason to halt construction.

The following is a list of specific comments on various aspects of the draft statement:

Page No.	Defect
1	The statement does not cover the effects of the Navajo Power plant, even though 25% of its power (and hence, its pollution) is attributable to the requirements of the C.A.P.
6	There will be four relift pumping stations along the Granite Reef Aqueduct. There is no discussion regarding the impact of these stations.
7	There will be a pumping plant on the Salt-Gila aqueduct. No mention is made of its environmental impact.
8	There will be two pumping plants along the Tucson aqueduct. No mention is made of their environmental impact.
10	Plans for the distribution system for delivered water are not finalized yet. The statement admits that "an accurate estimate of miles of main and lateral canals cannot be made at this time." This information should be available to the decision-makers before a decision is reached.

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[1] First Annual Report, pp. 13-14 (1970).

Page No.	Defect
13	The statement alleges that as an alternative to the Hooker Dam, four dam sites on the Gila River and two on the San Francisco River are being investigated. The statement does not indicate the location of those six dam sites or even whether they are in the Blue Range Primitive Area or the Gila Wilderness Area. The statement also says: "alternatives to other major features of the project are also being investigated." Those alternatives are not described with particularity. Hugh information gaps such as this are impermissible in a NEPA statement. In D.C. Federation of Civic Associations v. Volpe, _____ F.2d ____, 3 E.R.C. 1143, 1146-47 (D.C. Cir., October 12, 1971, No. 24,843), the plaintiffs called into question whether the Secretary of Transportation, in approving the design for a set of highway ramps and interchanges, followed the statutory requirement that "the project includes all possible planning to minimize harm to such park . . . or historic sites."[2] The court noted that such planning could not possibly have taken place, since the final design of the ramps and interchanges was not yet complete at the time the planning allegedly was done. The court commented: "absent a finalized plan for the bridge, it is hard to see how the Department could make a meaningful evaluation of 'harm.'" Similarly, in this draft statement, the Bureau of Reclamation could not possibly have assessed the environmental impact of the Hooker Dam, when it is not even sure of its ultimate location.
14	Some parts of the aqueduct will be fenced to protect wildlife. Other parts, that are not "wildlife crossings and natural migration routes," will not be fenced. What will happen to game in those areas?

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[2] 23 U.S.C. § 138.

Page No.	Defect
14-17	The report analyzes in great depth various types of wildlife drinking facilities, but admits that the project as presently funded does not contemplate construction of such facilities. It is indicative of the one-sided orientation of the statement's drafters that they devote three pages to an elaborate description of "wildlife benefits" that are almost sure not to come about, while the potentially disastrous increase in lower Colorado River salinity that will result from the C.A.P. operation is totally ignored.
18	The statement says that disposal areas will be revegetated. It does not say how this can be accomplished, especially under the severe, arid desert conditions prevailing in the area.
18	Quarry sites will be in "remote areas" and will be left in a condition that will "minimize the impact on aesthetics and will not endanger wildlife." The location of these sites is not specified, nor is the method for restoration.
19	There will be a great deal of additional fishing at the reservoir along the stream. There is no mention of the potential environmental dislocation to be caused by more people and their cars.
19	The Bureau admits that there may be "many other possibilities of environmental enhancement, protection, and mitigation features" that may be appropriate. These features will be considered "as they become more specificly identified and evaluated." Obviously there is no way for a reader to assess the effectiveness of these measures at this time.
22	Instead of describing the vegetation found along the right-of-way, the statement refers the reader to various scholarly papers. The same is true for fauna. These papers are not readily accessible to the general public. The information contained in them should be set forth in the statement, itself.
24	Several rare and endangered species of animals are listed and the conclusion that "construction of the project is expected to have only minimal effect on rare and endangered forms" is expressed. There is no data supporting this conclusion.

Page No.	Defect
25	Unspecified recreation facilities are to be considered later. This is another example of the drafters' claiming benefits for the C.A.P. that may never materialize.
27	There is no discussion of the effect of the Lake Havasu water intake facilities on fish in the lake.
29	The statement admits that most of the canal right-of-way will contain a power line and maintenance road. There is no discussion regarding how these facilities will affect aesthetic values in the area.
29-30	The statement admits that there will be "major ecological changes" resulting from the construction of the reservoir. It also mentions "alteration of the original stream species." For "alteration" one should read "obliteration." *Cf. Environmental Defense Fund v. Corps of Engineers*, 325 F.Supp. 728, 749. The statement admits that the Bureau has no information regarding fishing along the Gila River. It also indicates that there will be some "alteration" of fauna. There also will be a reduction in habitat. But the extent and nature of such alternations and reductions is not specified.
33	The statement indicates that there will be a net gain in recreation because of the Charleston Reservoir, since there is a scarcity of "large recreational lakes" in the area. It does not mention the corresponding loss of recreation in the free-flowing streams there.
34	The Charleston Reservoir "will have the greatest impact on archaeological values of the four project reservoirs." That impact is not specified.
34-35	It is impossible to learn anything about the effects of the Hooker Dam Project, since its exact location is not specified.

Page No.	Defect
37	The statement maintains that "the stream flow regimen of the Colorado River below Parker Dam will be unaltered by the diversion of C.A.P. water." Certainly, there will be an increase in salinity and a decrease in the amount of water available downstream. In the draft impact statement for the Navajo Project, it is admitted (page 48) that withdrawals from the Colorado River of about 100,000 acre feet by five power plants would increase downstream salinity by "less than 1/2 percent." Since the C.A.P. will withdraw about twelve times that amount, we can expect an increase of about 5-6%. This could prove disastrous to downstream users. The statement does not even mention the inevitable salinity problem.
38	The statement admits it is not possible at this time "to assess in detail the effect that Colorado River import water will have on the beneficial use of existing supplies in the service area of the project." This data should be supplied in the statement.
39	The policy on use of pesticides and herbicides is ambiguous. The reader is unable to learn if pesticides will be used and, if so, the exact quantities involved.
40	The statement indicates "the rate of population growth can be expected to continue with or without the (C.A.P.) project." It also says "increasing the supply of water will circumvent drastic curtailments of the present rate of population growth . . ." The former assertion is absurd; obviously, the availability of a huge new influx of cheap water will serve to attract additional population and industry. The latter statement indicates that the Bureau of Reclamation is committed to maintaining the present cancerous growth of population in Phoenix and Tucson.
40	The statement claims flood control benefits for the project. I doubt that there are many floods of severe magnitude in the Salt and Gila Rivers.

Page No.	Defect
43	The statement admits that there are wildlife "hazards associated with high volume canals." It proposes to neutralize these hazards by drawing wildlife away from the canals with ponds, "back water fingers," and "guzzlers," although there is no money to build any of these facilities. Therefore, this proposed solution is chimerical.
44	The statement notes that the Arizona Game and Fish Department wants up to 60,000 acre feet to develop 50 new fishing lakes in the mountains. What would be the environmental effects if these lakes are constructed?
45	The statement admits that there is no data concerning the effects of increased accessibility to the aqueduct area and also admits, "it must be recognized that other beneficial or detrimental effects, not presented in this statement, will occur." Finally, it admits that there is absolutely no knowledge concerning "economic and sociological impacts resulting from the project." These are all serious omissions.
46	The statement admits the aqueducts may have an effect on the migration of big game, but does not specify those effects.
47	The statement admits that certain species may be eliminated altogether. Which species are these?
47	New species may be admitted into the Salt River-Gila River system from the Colorado River and may affect the ecological balance there. No specifics are given.
48	It is indicated that ground-water recharge may be reduced downstream. Where, and by how much?
48	At the top of the page, the statement admits that increase in population density may have an adverse environmental impact. Yet at the bottom of the page, the alternative of not building the project is dismissed because it would hamper increases in population, standard of living, agriculture, and industry.
52	The statement admits "the long-term effects of the project will be to provide for continued urban and

Page No.	Defect
	industrial growth . . ." Notice that the statement does not mention the long-term needs of preserving stream flow in the Colorado River or of the need to discourage the continued in-migration to the desert southwest, a fragile area that cannot support indefinite growth.
54	Again, the statement indicates that existing and endemic biological populations will be changed. These changes are not elaborated. Note also that 72,000 acre feet of water a year will be evaporated. It should be noted that the statement does not even mention how much water the C.A.P. will divert from the Colorado, and does not mention this hugh diversion as an irretrievable commitment of resources.

The final and most serious defect in the statement from the Chemehuevis' point of view is its complete disregard of the devastating effect the C.A.P. will have on the environment of the Indians. The statement does not even mention that the Orme reservoir will wipe out almost 2/3 of the Fort McDowell Reservation. Nor is any concern expressed for the effects of the C.A.P. on the water rights of downstream Indian reservations. The Supreme Court recognized in Arizona v. California, 373 U.S. 546 that Indian lands are essentially "useless" without water and, therefore, the Colorado River tribes were entitled to enough water "to satisfy the future as well as the present needs of the Indian Reservations . . . and to irrigate all the practicably irrigable acreage on the reservations." (373 U.S. at 600). The five Colorado tribes were awarded a priority right to 905,496 acre/feet by the Supreme Court, almost 783,000 of those acre/feet to reservations downstream from the C.A.P.

The Colorado River is already overdrafted. Existing water uses without the C.A.P., for the years 1961-65 for California, Nevada, Arizona, and Mexico, plus losses from evaporation totalled 9,628,600 acre/feet;[3] more than 2 million acre/feet more than the entitlement of the Lower Basin states under the

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[3] Senator Clifford Hansen in Congressional Record, vol. 113, p. 21375, August 3, 1967.

Colorado River Compact of 1922. When the Upper Basin states use their full entitlement, as they soon will, there simply will not be enough water for the C.A.P.[4] At that point, the government will be faced with two possible alternatives. It could shut down the project, thereby sacrificing several billion dollars' investment and suddenly cutting off from Phoenix and Tucson a source of water on which their expanding populations will have come to depend. Or, as appears more likely, the government could appropriate Indian-quaranteed water to make up the difference. The first choice is politically and economically unthinkable; the second is illegal and immoral.

The Colorado River tribes' water is threatened not only in quantity, but also in quality. The Colorado River already contains 1,000 parts of salt per million. That figure will expand to 1,400 parts per million, nearly three times the amount considered tolerable by the Public Health Service, unless 2-2 1/2 million acre/feet of relatively pure upstream water is available for dilution purposes.[5] Construction of the C.A.P. will eliminate one-half this needed margin. According to the criteria for irrigation accepted by the State of California,[6] water of 1,000 p.p.m. is marginal, and at 1,200 p.p.m., it enters into the realm of "injurious to plants." Thus, the Central Arizona Project threatens to nullify the Indian entitlement to water decreed by the Supreme Court, even if the requisite number of acre/feet are available, since that water will be unusable for irrigation. It is almost inconceivable that a potential environmental effect of such grave magnitude could have been overlooked entirely in the draft statement.

I hope these comments prove useful. I assume that commencement of construction on the C.A.P. will be delayed until the questions raised in this letter are answered.

Yours truly,

Joseph J. Brecher

JJB:fpp

Joseph J. Brecher

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[4] See article by Edwin C. Johnson, Congressional Record, vol. 113, pp. 21657-60, Aug. 7, 1967.

[5] Congressional Record, vol. 114, p. 13426, May 15, 1968. This dilution effect has already been recognized by your Division. See Environmental Statement, Navajo Project, p. 48.

[6] Criteria established by Dr. L.D. Doneen.

MR. STEIN: Any comments or questions?

MR. DICKSTEIN: I don't quite understand where the Clean Air Act enters into this.

MR. WILKINSON: Well, as we state on page 3, we think that this does give EPA the power to submit comments on the draft environmental--

MR. DICKSTEIN: We always had the power under the original CEQ act. The Clean Air Act involves air. We commented on the impact of air problems under that particular act. And we do have the power, but under the CEQ. I don't understand. I think it is just something misunderstood, really.

MR. WILKINSON: Well, our point is the comment.

MR. DICKSTEIN: There is a way, yes.

MR. WILKINSON: Right, that is the point.

MR. STEIN: Any other comments or questions?

If not, thank you very much.

MR. WILKINSON: Thank you again, Mr. Chairman.

MR. STEIN: Let's go on with Nevada.

MR. WESTERGARD: I would like to introduce Don Paff, who is the Administrator of the Colorado River Commission of Nevada.

DONALD L. PAFF

ADMINISTRATOR

COLORADO RIVER COMMISSION

OF NEVADA

LAS VEGAS, NEVADA

MR. PAFF: Thank you, Roland.

First of all, I would like to remind my friend Myron Holburt that Nevada is also a Lower Basin State, participates in the burdens of the mineral quality of the Colorado River. We are also a water user.

Mr. Chairman, thank you for the opportunity to present the Colorado River Commission of Nevada's comments at this conference. It was our understanding that the conference discussions would be primarily directed to the subject of mineral quality as identified in the Environmental Protection Agency's report "The Mineral Quality Problem in the Colorado River Basin" dated 1971. Our comments will be generally confined to that report and the draft of that report dated November 1970.

The Colorado River Commission of Nevada has viewed the increasing salinity of the Colorado River as a matter of great importance. Recently placed into operation in southern Nevada is a water treatment and transmission system to further develop

Nevada's allocation of Colorado River water. Thus the major municipal and industrial supply to southern Nevada will be from the Colorado River. Increases in river water salinity places an additional burden of cost on the people of Nevada for the Southern Nevada Water System and other water facilities. Salinity control measures are necessary to abate and possibly reduce salinity levels in the river.

As an agency of the State created in 1935, the Colorado River Commission of Nevada is empowered to receive, protect, safeguard and hold in trust and administer for the State all water and water rights and all other rights and interests or benefits in and to the waters of the Colorado River and to the power generated thereon or which hereafter may accrue to the State of Nevada. Within this responsibility our comments on the 1970 draft were discussed with Nevada's conferee and incorporated in his letter to the Environmental Protection Agency on June 4, 1971. A copy of that letter was incorporated in Appendix D of the 1971 report.

We have found no reasons to modify the major points of our previous comments. However, we wish to reaffirm our present basic position relating to Colorado River mineral quality and we strongly urge the conference adopt these positions.

We believe that:

a) a broad Colorado basinwide mineral quality policy should be adopted that would have as its objective the maintenance of lower main stem salinity concentrations at or below present levels;

b) in the broad quality policy implementation, the problem should be treated basinwide, recognizing that with the Upper Basin continuing to develop its Compact allotment, salinity levels may temporarily rise;

c) no numerical criteria or standards be adopted until the effectiveness of present and future State and Federal Colorado River salinity control programs are better known;

d) the Bureau of Reclamation should have primary responsibility for investigating and implementing a basinwide salinity control program with other Federal agencies assisting and consulting with the Bureau of Reclamation to achieve maximum effect in the salinity control program.

The Colorado River Commission of Nevada supports an aggressive salinity control program which, in our opinion, can only be brought about by a continued cooperative attitude between the Federal agencies and the Colorado River Basin States. The Commission has and will continue to participate and support programs to control the mineral quality problem in the Colorado River Basin.

MR. STEIN: Thank you.

MR. PAFF: Thank you, Mr. Chairman.

MR. STEIN: Any comments or questions?

I don't have any because it will just be repeating. Either the States have gotten together or there is remarkable unanimity of opinion. (Laughter.)

MR. PAFF: Mr. Chairman, we would suggest that, as has been said before, Nevada supports what we think is a consolidated position of the seven basin States.

Thank you.

MR. STEIN: The word "consolidated" is yours. (Laughter.)

Mr. Westergard?

MR. WESTERGARD: I think that concludes for now. Otherwise, Mr. Chairman, I would be in a position similar to you, I would be guilty of repeating.

MR. STEIN: That is my function. (Laughter.)

New Mexico.

MR. WRIGHT: Mr. Stein, Mr. Reynolds, Secretary of the New Mexico Interstate Stream Commission, would like to present some statements for the State of New Mexico.

S. E. REYNOLDS
SECRETARY
NEW MEXICO INTERSTATE
STREAM COMMISSION
SANTA FE, NEW MEXICO

MR. REYNOLDS: Mr. Chairman, my name is S. E. Reynolds. I am Secretary of the New Mexico Interstate Stream Commission.

By letter to Mr. Wright, New Mexico's conferee, dated June 24, 1971, I commented on behalf of the Interstate Stream Commission on the draft report of the EPA. Those comments are included in Appendix D of the EPA report, which I am advised has been made a part of the record of this conference. The substance of those comments remain as applicable to the revised report as they were to the draft report and I ask that they be so considered.

Just to summarize the Commission's position, Mr. Chairman, we concur that an objective of maintaining salinity concentrations in the lower main stem of the Colorado River at or below present levels should be adopted. We think that numerical salinity standards under the Federal Water Pollution Control Act should not be adopted. We urge that the seven States and the EPA aggressively and energetically support the U. S. Bureau of Reclamation salinity control program.

I might digress, if I may, for just a moment, Mr. Chairman, in view of the recent comments concerning transmountain diversions and point out that the ultimate effect of a transmoutain diversion is to improve the quality of water. The water diverted, of course, is relatively pure, but some salt is diverted with the water. The alternative, of course, is the consumptive use of that same amount in-basin, leaving the full load of salt within the basin.

MR. STEIN: Steve, I am glad we are having this meeting here and not on the Columbia River after making that statement. (Laughter.)

MR. REYNOLDS: Mr. Chairman, one further point of a technical nature. In considering the merit of the Bureau of Reclamation's proposed program or other measures to alleviate the salinity of the Colorado River, one must keep in mind the point that I think is well made in the EPA report, which is that more than 80 percent of the projected increase in salinity is due to the concentrating effect, not to a loading effect.

Mr. Chairman, I am gratified that you have seen so clearly that the unity on salinity among the Colorado River States is unique, and I hope that you will handle that structure with great respect and great care.

Thank you. (Laughter.)

MR. STEIN: Possibly we have a basis for an approach if the objective is to lower the salinity. It is pointed out, if we have achieved nothing else but created a unanimous position among the seven Colorado Basin States, I think we might go down in history as honored heroes of the Republic. (Laughter.)

MR. REYNOLDS: Mr. Chairman, your conference may have contributed more to that than you understand. (Laughter.)

MR. STEIN: That is right. No, I know that. (Laughter.)

Are there any other comments or questions?

MR. WRIGHT: Mr. Reynolds, Mr. Stein mentioned that it appeared that the States have gotten together. I think that maybe a point should be made that we started getting together in 1960. In 1963 we asked for the study to start with as a basin unit, and the conferees, and I am not sure that you need to explain it necessarily, but I can say for the pollution control people of the States, we have been in correspondence ever since 1960. During the establishment of the present water quality standards we had numerous meetings all over the basin.

Maybe you should comment for the Chairman on whether or not the water resources type people have conferred on this subject.

MR. STEIN: Do you care to comment?

MR. REYNOLDS: This probably need not be said. Certainly they have.

MR. STEIN: That is right.

MR. REYNOLDS: And properly so. Mr. Chairman, I might say that some of the States have been working at this since about 1912.

MR. STEIN: That's right. That is what I was going to say to Mr. Wright. And here is the big difference, really.

I know the States here have been getting together at least since 1912, but most of the times in those early days you were getting together in court. (Laughter.) And let me contrast this to what we have done here. Maybe we have helped it.

But I remember very clearly--maybe you were there, Mr. Reynolds, I don't recall--we once had a meeting down in Phoenix, and I remember we didn't have a map of the basin such as is behind us, and we asked the people down there to get us a copy of the map. Of course that was when the great case between

Arizona and California was going on.

A map was put up and there were some little numbers around the map, and suddenly there was a hum in the hall and the hum increased and increased. That was before we had the disturbances. I guess you all know about that as I know too well. But I just couldn't continue with the meeting.

Then I turned around to the map, and it developed that these numbers were the numbers that Arizona was putting forth as the acre-feet that it required, or thought it was entitled to. in the lawsuit, and there was no holding the meeting. (Laughter.)

And I said, you know, let's try to discount those numbers. They are just numbers on the wall. All we have the map up here for is to show the basin and the tributaries.

And after I made what I thought was a reasonable statement, everyone quieted down. I thought we would continue with the meeting. That lasted about 5 minutes and then the hum began again. They just couldn't stand looking at those numbers. So I had to give up and take it down. (Laughter.)

I think things are different now.

MR. REYNOLDS: Much different.

MR. STEIN: And really much better, right.

MR. REYNOLDS: I agree, sir.

MR. STEIN: Right.

Any other comments or questions?

If not, thank you very much.

MR. REYNOLDS: Thank you, Mr. Chairman.

MR. STEIN: May we go to Utah.

MR. THATCHER: Mr. Chairman, I would like to follow the pattern that the other conferees have developed and ask Utah's invitees to make statements. I have had some response from our invitees, but no specific indication that any of them wanted to make a presentation.

So let me just say that if any of Utah's invitees are in the audience and if they would like to make a statement, now is the time to come forward.

Apparently there are none.

I have a brief prepared statement, Mr. Chairman, and I believe I have enough copies for one for each State conferee, one for the Chairman, and one for the reporter.

LYNN M. THATCHER

DEPUTY DIRECTOR OF HEALTH

UTAH STATE DIVISION OF HEALTH

SALT LAKE CITY, UTAH

MR. THATCHER: This statement is supported by the Utah Water Pollution Committee and the Utah Division of Water

Resources and it is really in summary form, so I will read it hurriedly.

I want to begin by expressing thanks to the Environmental Protection Agency of the Federal Government, and its predecessors, for their accomplishment in making available the report on the Mineral Quality Problems in the Colorado River Basin. This report resulted from one of many recommendations made by the conferees, exemplifying the need for Federal resources to accomplish development of information required to set up a fair, practicable, and enforceable program for control of pollution in the Colorado River.

I must point out that while I served for a period as temporary chairman of the Colorado River conferees during the time that an agreement was being developed for selection of water quality standards, I do not at this time have any such relationship to the group, and my statement is not in any way related to any formal action by them. In fact, since the agreement on development of standards was achieved by the conferees in 1967, no further formal action on this matter has been considered necessary, pending completion of studies under way at that time.

The previous action of the conferees to set standards, but to temporarily exclude specific standards on salinity, was based on the concept and acknowledgement that ultimately, when sufficient information becomes available, specific standards will be set for all essential parameters. The Mineral Quality Problems report mentioned provides part of the information needed to accomplish pollution control. Our deliberations on this report should guide us on a continued course of action toward the ultimate objective of water quality management.

The three recommendations which emerged in the final EPA report lead me to propose more specific recommendations as follows. These are in harmony with Utah's previous comments on the report.

1) A salinity policy should be adopted for the Colorado River System that will have as its objective the maintenance of salinity concentrations at or below levels presently found in the lower main stem.

2) Implementation of this salinity policy objective for the Colorado River System should be accomplished with acknowledgement that the salinity problem must be treated as a basinwide problem that needs to be solved to maintain Lower Basin water salinity reasonably near present levels while the Upper Basin continues

to develop its compact-apportioned water, recognizing that salinity levels may rise until control measures are made effective.

3) The adoption of numerical criteria should be deferred until the potential effectiveness of the Colorado River salinity control program is better known and because with the present level of information it is not possible to establish equitable, practicable and enforceable numerical standards.

4) The Bureau of Reclamation should be assigned the primary responsibility for investigating, planning and implementing a basinwide salinity control program in the Colorado River System, in order that Federal funds can be properly assigned for solution of this truly interstate problem.

5) The Environmental Protection Agency should continue its dedication to the program by consulting with and advising the Bureau of Reclamation, accelerating its ongoing data collection and research efforts, and

transferring funds to the Bureau of Reclamation.

6) The Office of Saline Water should contribute to the program by assisting the Bureau of Reclamation as required to appraise the practicability of applying desalting techniques.

7) The Congress and administration should be urged to accelerate the salinity control program, including appropriation of adequate funds.

In support of these recommendations, it is pointed out that language of the Federal Act under which the conference was called seems to lead ultimately to the concept of "remedial actio with respect to pollutants entering the river system. The proposed salinity control program by the Bureau of Reclamation certainly can be regarded as remedial action and seems to satisfy the intent of the law and also to support the concept of no numerical standards at this time because the very accomplishment of the suggested objectives of the Bureau will provide us with necessary information to establish such standards in a fair and equitable manner. It should be pointed out also that every State has been in the process of taking important remedial action since the conference was first organized and even before the seven States came to an agreement on the establishment of water quality standards. This consists of reviewing plans for new developments and imposing necessary controls. Without such controls, many new sources of salinity could have developed and increased the salinity problem throughout the basin.

It must be stressed that delaying establishment of numerical salinity standards will not diminish these remedial actions, but that setting such standards with present inadequacies of knowledge could result in unsound, inequitable, and unenforceable standards.

Let me also throw out the caution that the concept of singling out the salinity problem and taking action with respect to it alone, apart from other conference activities, denies the basic fact that no part of a pollution problem can be separated from other parts. Salinity, radioactivity, heavy metals, bacteria, viruses, all are part of the pollution picture and have to be considered as an integrated whole.

Much has been said in the past about the need to augment the conferees by bringing in representation of other resource interests in each State. This has always been recognized as a valid concept, and to my knowledge has been implemented in most cases. If the water resource groups in the various States feel they have not had adequate representation in the quality problem, certainly something must be done about it, and I, for one, would accept practical suggestions as to how the conferees group could be properly augmented by others. I do not feel this problem has occurred in Utah, but I still would be receptive to some modified approach which satisfied all groups in all States.

I then continue with a reference to the uranium tailings problem. I needn't get into that now because we covered that yesterday, but add only one thing that really goes without saying:

The EPA is making some efforts in financing research projects that have a direct bearing on this problem. I would hope that these would continue and even be accelerated. One specifically that I have in mind is a research program by Utah State University in Utah's Uinta Basin area which goes directly to this question of application of irrigation water to the soil and is intended to eventually come up with facts that may help us solve the salinity problem.

Thank you, Mr. Chairman.

MR. STEIN: Thank you.

Any comments or questions?

MR. WRIGHT: Mr. Stein.

MR. STEIN: Yes.

MR. WRIGHT: Mr. Thatcher, on page 3, Item 7, I noted the phrase "salinity control program."

> The Congress--I am not sure that is the paragraph I had in mind, but let's use it--
>
> The Congress and administration should be urged to accelerate the salinity control program, including the appropriation of adequate funds.

The phrase "salinity control program" refers to what Mr. Ellis Armstrong presented yesterday and entitled it the Water Quality Improvement Program, is that correct?

MR. THATCHER: Yes, I would accept any change in terminology that relates to what the Bureau has in mind.

I think that is all I have, Mr. Chairman.

MR. STEIN: Any other comments or questions?

If you really thought so much of us, you thought we were saints. I like that No. 5 where you say, "The Environmental Protection Agency should continue its dedication to the program by transferring funds to the Bureau of Reclamation." (Laughter.)

MR. THATCHER: You say you like that or you don't like it?

MR. STEIN: Well, I didn't know you really thought we were that pure. But that's great. I am glad you think that highly of us to make that suggestion.

Any other comments or questions?

If not, may we go to Wyoming.

MR. WILLIAMSON: I don't nor have not been contacted by anybody from Wyoming to make a statement and I have only seen one familiar face from the State around here, so I will ask if anybody from Wyoming would wish to make a statement at this time. I doubt if there is anyone here for that purpose.

I do not have a formally prepared statement at this stage. However, I think I would like to make one or two comments about what is going on here, if that would be possible.

ARTHUR E. WILLIAMSON
DIRECTOR OF SANITARY ENGINEERING SERVICES
DEPARTMENT OF HEALTH & SOCIAL SERVICE
CHEYENNE, WYOMING

MR. WILLIAMSON: There has been much discussion of standards, and I would say that we are as a State in conformance with the others here that we do not feel a numerical standard is wise at this time and that we certainly support a good policy for the control of salinity.

This matter of standard setting to me gets down with argument here State versus Federal. I can see the Federal reason for wanting a standard set. But I also can see the reason why the States do not want it set, and it is surprising that it is the States that are on the firing line, that are really doing the enforcement on these standards when they are set.

And all of the regulatory agencies have had enough experience with standards at this stage in the game that they can only say we don't want a number written down at this stage because we know what the problems of enforcement are, so we are unanimous that this isn't going to give us anything but a headache if we start putting that number on paper. So this is probably why we have got such good agreements in the States. Past experience does pay off.

Now, as to policy, I think we have pretty good policies developed over the past 6 years, anyway, from the time we started thinking about setting water quality standards in 1965. The States did have a number of meetings in which we discussed water quality standards — what was going to be our policy, how we should work towards controlling salinity in the Green River. And I think some of that existing agreement is still a pretty good framework to have around. So I am sure we will come out with a workable policy on this matter.

Now, yesterday was interesting and I think Murray got it read into the record, anyway, that we are dealing with unconventional sources when we are looking at irrigation. I will certainly agree with him that these are unconventional sources compared to the other types of pollution which we handle.

Certainly they call for unconventional methods of control. We cannot go back to that point source and say, you have got to plug it up. So we have to start looking at these unconventional methods, and I think many of them have been brought out here, touched on a little bit but not quite clarified, but that we are going the right way.

I think we have to gear our program to the policy we developed. Let's get going, let's carry out something to show that it can be done, rather than following again the conventional means of gearing your policy more or less to conventional financing. In other words, if we have to go through 3 years of our feasibility reports, argue with committees for appropriations for a number of years, we are not going to show much success on our accomplishments.

So I would hope that we can become unconventional here and say, let us get a project started, let's pick a good big project we know something about, particularly in the irrigation field, where something can be done and let's use some unconventional method of financing to get the thing started next year instead of waiting 3 or 4 years. And I think this can be accomplished with the proper application of powers at various points. I think if we let our wishes be known along this line that it will occur.

So let's take a real hard look at this unconventional type of thing and maybe we can get the wheels turning here next year instead of 6 years hence. This is the one big hope I would like to see.

We got in a little bit of argument here yesterday also about where do we treat, at the source or the point of diversion. The only judgment I could make on that, we are probably going to be doing both of them. We are not really saying that treating at the diversion is a method of salinity control. We are probably going to say it is a necessity to give good quality water to the people that want it. Because even if we develop our irrigation efficiencies up to 100 percent or something like this, we get our salt balance taken care of, we are just taking out what we are putting in. This matter of consumed water is going to whip us, even though we still have that water in the stream and we haven't added anything. Just the concentrating effect is probably going to require somebody to desalinate it at some point to give them a little better quality of drinking water if they want or industrial water or possibly agricultural water. So I think we have to consider this as an adjunct rather than as a control method. Certainly it has many possibilities. And we don't want to hang at this time, in my book anyway, a lot of faith in controlling these natural sources.

Now, it is a possibility, we have got to look at it, we are going to have to spend some money on it. Somebody said we hadn't referred to the Ark-Red study. I know this is one of the first ones in the country. I followed it quite a while when they were doing on it and just recently talked to one of the boys who was on the project, and they had some big salt springs down in that country. They did manage to stop the flow from these salt springs, but they didn't change the salinity in the river one bit. These things have a habit when you plug up a hole and stop it flowing they come out some place else, and they got wide diffusion of salt water back in the riverbed.

Well, these are some of the technical aspects I think we are looking at when we are looking at natural sources. It sounds easy to say you can go out here and plug a hole and stop water from coming out of it, but you have got to remember that water has been running there several million years, it came out of there for some reason. That was probably because the pressures got too high. And if we plug them up the pressure is built up again and it is going to come out somewhere.

So we may just be diffusing the problem, but this certainly has to be looked at, it has to be studied, what are the potentialities. So if we hang our faith in a standard on removing so many tons of salt from natural sources we might be kidding ourselves at this stage in the game.

So these are just some of the aspects that may or may not have been thought of that I would like to bring to attention at this time.

I think that is all the comments I have.

MR. STEIN: Any comments or questions?

I think a point of clarification. I think I agree with you when you talk about this problem that we need unconventional methods of solution and unconventional financing. As I think has been a pretty close history of the development of water resources in the West, the conventional financing has been Federal financing. The question I have to ask you, does that unconventional financing mean you are proposing State and local financing? (Laughter.)

MR. WILLIAMSON: No, I am not talking of that, Murray. (Laughter.) I am talking about the long rigmarole it usually takes to get Federal financing through. I think there are probably some quicker avenues that can be used at this time rather than going before the Appropriations Committee year after year.

MR. STEIN: Thank you.

We have one more we are going to call before recess. Marianne Slagle, Sierra Club.

MARIANNE SLAGLE

SIERRA CLUB

LAS VEGAS, NEVADA

MS. SLAGLE: I am Marianne Slagle from Las Vegas, Nevada, a member of the Sierra Club, and I am going to be reading a letter from John McComb of the Sierra Club addressed to Paul DeFalco, Administrator of the EPA, Region IX. Any questions, since I didn't write this, should be addressed to John McComb, Chairman of the Sierra Club, Southwest Office, 2014 East Broadway, Room 212, Tucson, Arizona, 85719.

(The letter referred to follows:)

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Sandstone Sculpture, Peach Wash, Arizona

SIERRA CLUB *Southwest Office*
2014 East Broadway, Room 212, Tucson, Arizona 85719

February 3, 1972

Paul DeFalco, Administrator
Environmental Protection Agency
Region 9
760 Market Street
San Francisco, California 94102

Dear Mr. DeFalco:

Thank you for sending me a copy of your report, The Mineral Quality Problem in The Colorado River Basin. The wealth of information contained in this report is very much appreciated.

Virtually everyone, whether he be a Sierra Club member or a representative of a state water agency, agrees that a salinity control program is needed for the Colorado River Basin. However, judging by the comments by state agencies, contained in Appendix D, this appears to be about as far as they want to go. Water resource development agencies appear to be opposed to any meaningful program that might interfere in any manner with their plans.

In our opinion, numerical water quality standards are absolutely necessary if anything is to be accomplished about the salinity problem on the Colorado River. These standards or criteria should initially provide for no further degradation of the water quality. This means that any developments that would tend to increase the salinity must be accompanied by suitable counterbalancing control measures. The long term program should hope to correct many of the existing manmade salinity problems in the basin. A timetable calling for decreasing salt concentrations in the Colorado River should be established to meet this goal.

The report outlines three general alternatives whereby salinity control might be effected. These were limitations on further development in the basin, reduction of salt loads, and augmentation of the water supply. From our point of view, there should be much more emphasis given to the alternative of limiting further development and thereby depletions of the water supply.

The existing plan of virtually every water resource agency in the Colorado River Basin is to "completely develop" their share of the Colorado River water. It is a fallacy to believe that we can undertake this level of development with the accompanying build up within the basin of dissolved solids which formerly were discharged into the Gulf of California without in the long run having some peculiar problems. We hope that the long range implications of this level of development will be carefully studied by your agency.

The report dismisses the alternative of limiting further water resource development in the basin with the comment that it "had the obvious disadvantage of possibly stagnating growth of the regional economy." As you already know, the growth philosophy is increasingly under attack. We believe that it is unfortunate that the Environmental Protection Agency has dismissed the development limitation alternative without giving it more serious consideration. This alternative is clearly unacceptable to the water resource development agencies in the various states of the Colorado River Basin. It is doubtful that these same agencies will ever do what is needed to control the salinity if it means that some water resource developments have to be foregone. It is not clear however, that this alternative is unacceptable to many of the residents of the area. We believe that the more emphasis on this alternative would be welcomed by that increasing segment of the public which is concerned with our present indiscriminate quantitative growth without any regard for the quality. The combined economic and environmental cost of "complete" water resource development in the Colorado River Basin including the cost of increased salinity would in all probability exceed the benefits from this development.

The existing compacts and other legal institutions which apportion the water among the various states should not be regarded as a license for any form of development at any cost in the Colorado River Basin. The alternative of limiting development has many political, economic, and environmental ramifications, but it should definitely not be dismissed as casually as has been done in the report.

Obviously, the major brunt of any development limitations would be born by the upper basin states, since the lower basin states already are or shortly will be using their entire entitlement. However, salinity problems in the lower basin should not be ignored. For example, the Welton-Mohawk Project appears to be particularly unfortunate when its impact on the salinity of water delivered to Mexico is taken into consideration. Quite possibly this project should never have been undertaken. The cost in terms of increased salinity as a result of diversions for the Central Arizona Project should also be carefully evaluated before any irrevocable decisions are made and construction begins.

Augmentation of the water supply, whether by trans basin diversion, weather modification or importation of desalted sea water is generally not an acceptable alternative to us at this time. Trans basin diversions are both economically and environmentally unsound and probably politically unrealistic. While flow augmentation by weather modification appears to have some promise for providing additional water at low cost, the environmental effects of weather modification are at best very poorly known at this time. This alternative should not be promoted until much more thorough research has been done into these effects. The same is generally true of importation of demineralized sea water.

We generally agree that programs to reduce salt loads should be pursued. However, the control programs should be directed primarily at man caused increases in the salt load. Many of the natural sources of salt are also features of outstanding natural interest. Attempting to control them could result in destruction or impairment of significant natural values.

One example of this which I would like to cite is Blue Spring on the Little Colorado River. Your report correctly notes that Blue Spring is the largest single point source of dissolved solids in the Colorado River Basin. The report also lists a potential project to control this source.

Blue Spring itself is one of the largest springs in the West and thus is of interest for that reason alone. The canyon in which it is located is an integral part of the Grand Canyon and it is spectacular in its own right. We would certainly oppose any significant construction within this canyon. Thirdly, the high mineral content of the water has formed a series of beautiful travertine dams in the thirteen miles between Blue Spring and confluence of the Little Colorado River with the main stream. The Little Colorado River and these travertine dams are a major feature of interest for boating parties in the Grand Canyon and virtually all of them stop at the mouth of the river.

Many other natural sources of dissolved solids have similar values which deserve protection. Programs which would affect these sources should very carefully weigh the economic benefit of reduced salt load against the adverse effects the control program would have on features of significant natural interest.

We hope to have someone present to observe at least part of the enforcement conference to be held on February 15-17, 1972, in Las Vegas, although we don't know who will be able to attend at this time. Col. Henry M. Zeller of 5120 West Via Mallorca, Tucson, Arizona, will be responsible for locating someone to attend the meeting.

The comments in this letter are based on discussions about the mineral quality problem with Sierra Club members throughout the Colorado River basin. We appreciate your soliciting our views. We also hope that you will continue to keep us informed of your agencie's actions concerning this matter.

Sincerely,

John A. McComb
Southwest Representative

JAM:ab

cc: Henry M. Zeller
Joe Brecher
Jack McLellan
John Barker
G. William Fiero
Roy Evans
Brant Calkin
Michael McCloskey

MS. SLAGLE: Thank you.

MR. STEIN: Thank you.

Any questions or comments?

As long as we don't have the letter writer, I would just like to make one point, read one sentence from the letter, and I think this is reflective of the entire letter, with the positions we have heard before. This sentence I would like to call attention to:

> In our opinion, numerical water quality standards are absolutely necessary if anything is to be accomplished about the salinity problem on the Colorado River.

I think we may have a diversity of opinion. (Laughter.)

Any other comments or questions?

If not, let us take a 10-minute recess. I urge you to be back on time because we have quite a few people to hear, and I would like to complete on time so we don't exhaust the reporter.

(RECESS)

MR. STEIN: Let's reconvene.

As far as I see the schedule now, I believe we will hear or be able to hear all the people who want to make statements tonight and the conferees will reconvene at 9:30 tomorrow morning. I do believe, as a matter of fact I am very hopeful, that we may have a statement by then. If not, you can watch us develop one or disagree. But I am always an optimist and I think we can make it. Our batting average is pretty high in getting unanimous agreements and I am going to hope until we don't.

MR. THATCHER: Mr. Chairman, can I raise a question?

MR. STEIN: Yes.

MR. THATCHER: Is there any chance that we could break the routine and meet a little earlier in the hopes of getting through earlier tomorrow?

MR. STEIN: Yes. What time do you want to meet earlier? 9?

MR. THATCHER: Earlier than that.

MR. STEIN: Here is my experience and let me tell you what happens. The reason I say 9:30, this is not just an accident. We have repeatedly scheduled meetings earlier than that. The difficulty is people don't show up, despite protestations to the contrary, and I recognize the town we are in. Now, if you want to meet earlier, I can be here, you know.

MR. THATCHER: I think we can get the conferees here by 8:30, couldn't we?

MR. STEIN: You poll them and see if they are ready by the end of the day. I will entertain that if you want to do it.

MR. WRIGHT: I am willing to work until 9 o'clock tonight.

MR. STEIN: No, no. The point is again, and I said this before, when attempting to get an agreement you had better take your time, because these rush agreements give you things to regret afterwards.

But I don't mind meeting any time, Lynn, that you can get the agreement here.

Now, when do you have to get out?

MR. THATCHER: Well, I haven't set my schedule yet. I want to step it up from tomorrow evening, which it is now.

MR. STEIN: Well, I would believe if you do your homework right, let's see how this goes and you get the feeling, we may just have an announcement here at 9:30 tomorrow without discussion.

MR. THATCHER: Well, could we make it at 8:30, the same as--

MR. STEIN: Well, as I say, why don't you check again.

MR. THATCHER: All right.

MR. STEIN: You check with the other conferees, but let's go through this and you check.

MR. THATCHER: Am I correct, one more thing, in the assumption that the record will be held open for people to submit statements--

MR. STEIN: Yes.

MR. THATCHER: --for a period of time?

MR. STEIN: Yes. I believe we said that would be a month.

MR. THATCHER: A month? All right, our Division of Water Resources wanted to submit a statement.

MR. STEIN: All right.

All right, let's go on. Gaylord Skogerboe.

GAYLORD V. SKOGERBOE
ASSOCIATE PROFESSOR
AGRICULTURAL ENGINEERING DEPARTMENT
COLORADO STATE UNIVERSITY
FORT COLLINS, COLORADO

MR. STEIN: I tried. Repronounce your last name for us.

PROF. SKOGERBOE: Yes. First of all, I answer to anything that comes close. (Laughter.)

MR. STEIN: I was pretty close on Gaylord, wasn't I?

(Laughter.)

PROF. SKOGERBOE: Yes. That is Gaylord Skogerboe, Associate Professor of Agricultural Engineering, Colorado State University.

I would like to point out first of all that I have two reports, one titled "Research Needs for Irrigation Return Flow Quality Control," which is presently at the Government Printing Office, should be available in April, and its EPA report, prepared by myself and Dr. James Loth at the Ada, Oklahoma, lab of EPA.

The second report I have is in this binder which was just sent out last Friday for review, which is the final report for the Grand Valley Salinity Control Demonstration Project.

This project was funded a little over 3 years ago, about 3-1/2 years ago, by EPA, its predecessor agency. It was a grant of $350,000 of Federal funds to a consortium of irrigation companies in Grand Valley. In addition these companies put up another $150,000 for the studies. The technical evaluation under this project was subcontracted to Colorado State University, and I was the project leader for Colorado State University on this effort.

The study was accomplished in a demonstration area which represents about 5 percent of the irrigated land in

Grand Valley; in other words, roughly 5,000 out of the 100,000 acres of irrigated land.

Under this project we were to line canals, originally we were supposed to do some work with drains. Our first effort was to evaluate seepage losses in these canals to make recommendations on construction. As we proceeded in the investigations, we soon discovered that the seepage losses were fairly low. Also that we had as a major problem the lateral system from the main canals. And so we proceeded with the construction program of lining about 8 miles of main canal section and about a comparable mileage of laterals.

Now, the results of this study show that we are annually removing about 5,000 tons of salt that formerly went into the Colorado River with this project, and if we used the damages in the EPA report at about the turn of the century, which was a little over $50 million, it would turn out on a 50-year repayment of 5 percent interest that we would break even on these costs. In other words, the downstream damages would pay for the cost of this canal lining. And of course if we go to higher damages which are reported in the Colorado River Board of California report on some other estimates that have been made of future damages, these benefits would be even higher. And again this doesn't take into account the benefits to the local people by accomplishing this canal lining.

Now, as part of our evaluation we had to put in a lot of instrumentation in the demonstration area so that we could do both water quantity and salt budgets for the area, and this required that we model the irrigation system, and the most difficult part was modeling the groundwater flow system. This required quite a series of piezometer measurements, we did a lot of drilling of wells down into the Mancos shale which underlies these soils, and were able to arrive at what we feel is pretty good information for this particular area of 5,000 acres.

Now, we soon recognized that the real important part of achieving salinity control in this demonstration area was on-the-farm water management. In other words, the key to accomplishing salinity control is to minimize the amount of water that passes below the root zone. Now, in irrigated agriculture we always have a requirement for a certain amount of leaching in order to maintain a salt balance in the root zone, but I think most of you in the audience recognize that in many of the irrigated regions throughout the West the deep percolation losses below the root zone far exceed the leaching requirements, and this is certainly the case in probably most of the Upper Colorado River Basin.

The other aspect that is required in order to accomplish on-the-farm water management is some rehabilitation work on the irrigation system itself and by a rehabilitation we mean some canal lining, we need flow measurement throughout the system--in other words, how do you manage the water if you don't know how much water you have got--and the operation and management of the canal system itself.

Now, these canal companies operate the canals, turn the water out at a turnout structure, and it is then turned over to a small group of water users who operate the lateral system. Some of these laterals are very well maintained. In fact, the farmers on some laterals have gone in and accomplished canal lining and improvements, but many of them are in a very poor state of maintenance. And one of our recommendations in this report is that the canal companies take over the operation of these laterals so that it can be operated as a more integrated type system.

Well, I would like to go from those recommendations into the results of this demonstration area and what it means valleywide.

First of all, by taking an input-output model, as was accomplished in the EPA reports, we can come up with the total amount of salt picked up in the Grand Valley area. But then the next question we have to ask ourselves, if we had no irrigated agriculture at all in this valley how much salt would we still be picking up in this valley? At the present time we don't have that answer.

Now, there have been a number of reports put out which have taken a certain proportion and assigned it to natural sources and a certain percentage to irrigated agriculture,and these percentages have varied. Our own educated question mark guess is that the large percentage of the salts are due to irrigated agriculture, but I can't say that I really know that answer. It is only a guess on my part after having worked with the system.

The second major area of question is if we were to go into a controlled program in Grand Valley and we were to cut by a half the amount of deep percolation losses, this is the water moving below the root zone, would we reduce the salt load or the salt pickup by a half that is returning to the Colorado River? Now, here again we don't have the answer to that question. And in the research needs report, which is a report to guide the EPA's research efforts in this area in the future, this is recognized as one of the very major areas of research to be accomplished in the near future, in what we call subsurface return flows and our ability to predict the chemical changes that occur in the water as it moves through the soil profile and returns back to the river system.

A second major area of effort required is economic evaluation. In a nutshell, what are the direct and indirect benefits in accomplishing any salinity control program? What are the benefits to the immediate area? And there are both direct and indirect benefits right in Grand Valley in accomplishing a salinity control project and, of course, the major benefits are really downstream in the Lower Basin States, both direct and indirect again.

But I would say these problems that I have cited are probably the simpler problems to attack. It is mostly a matter of putting in the funds to do the job.

The real heart of the problem, I feel, is water rights. And here I will just have to refer to my own judgments. I am sure many of you would argue very strongly with me. But I think what is needed is a change not in the western water laws but in the interpretation of western water laws. Somehow we need to build in some type of an incentive system for improved management of the water supplies that we have. At the present time to me it is very understandable why a group of farmers, an irrigation company, an irrigated valley, isn't about to give up the water rights that it established, say, at the turn of the century or prior to that time. These are held in very high regard, very important to the area, and they are very much afraid of giving them up.

Well, some economists have made suggestions that water should be placed on the open market. I personally feel that there should be some sort of an economic incentive system given to the irrigated area which would allow them, if they are to conserve water, to have some rights to turn around and either rent, sell, place or transfer that water and receive something in return. And I believe there are definite ways that this can be accomplished. I believe that States can put in certain safeguards to insure that the reallocation of those waters would fit into a Statewide water resource development plan and also safeguard against black market prices on the water.

Now, I would like to go into research and action programs. Since I am a university type and very heavily involved in research, probably many of you think, well, I have cited research needs and probably the type who could go on researching these same problems for 20, 30 years. Well, I think fortunately in this area of irrigation return flows that with the studies that have been conducted over the last few years and the few research efforts that we have, we can now proceed on a combined research and action program, with the research, of course, being the applied type of research.

G. V. Skogerboe

A good illustration of this would be, we could go into the irrigation scheduling as proposed by the Bureau of Reclamation in the Grand Valley area. We can proceed, realizing that by reducing the amount of deep percolation losses that we are going to have water quality benefits. The only problem is, as we proceed on that basis we don't know what those water quality benefits are exactly.

So one area that we could proceed along with is a study on these subsurface return flows and the effect of changing the amount of soil moisture movement and what its effect is on the chemical quality of the return flows.

Now, we presently have a proposal before EPA. This proposal was originally submitted about a little over 2 years ago requesting 95 percent Federal funding. I was told two things, first to get political support and secondly to only ask for 70 percent. And so I went to the State Legislature of Colorado and I really didn't give myself much of a chance, but a year ago they provided funding to match this particular project at this 30 percent level.

And a little history here. CSU was provided funds by the legislature for two new research projects, this one and one other one on pesticide research, the only two out of a request of probably 30 or 40 projects, so I felt very fortunate in that end.

Also we have a proposal before EPA which I am sure will be funded, and it has to do with the water quality aspects of irrigation scheduling and also combining irrigation scheduling with tile drainage, particularly on the lands close to the river which have been damaged substantially by irrigation return flows.

And also as a part of this last proposal, we are going to have a conference in Grand Junction. I hope most of you have read the posters outside in the lobby. A national conference on managing irrigated agriculture to improve water quality. It will be held May 16 to 18 at Mesa College in Grand Junction. The hosts for this conference are the Grand Valley Water Purification Project, which is the consortium of irrigation companies that took on this canal lining study, the Mesa College and the Grand Junction Chamber of Commerce and sponsored by EPA and Colorado State University. And I hope that most of you will take the time to attend this conference.

What we will be getting into in this particular conference is the variety of water quality problems resulting from irrigated agriculture throughout the West. We will naturally discuss the Colorado River Basin some, but we will be getting into discussions in the Columbia Basin, the San

G. V. Skogerboe

Joaquin in California, Rio Grande, other areas around the West, how some areas have survived the poor quality water, what are some of the potential solutions for alleviating these problems, including what are some of the economic questions, what are some of the legal questions. We will have a couple of sociologists who have studied irrigation systems, and last of all we will have a panel discussion on implementing control programs.

My final statement, I would like to make a self-evaluation of the statement by Ellis Armstrong yesterday, particularly in regards to looking at their schedule for between now and 1981, I believe, their particular program. I think that, of course, this schedule could be speeded up by additional funding, but I think that we have a problem here when we go into an action program in a particular area. It is not just a simple matter of putting up so many million dollars and achieving salinity control. I think there is a certain amount of time-effort required to move into an area, develop a feel for the system, develop a rapport with the people to get them working with you on this. I also feel that it is a problem which involves not just engineering. It is a problem involving salt physics, salt chemistry, engineering, economics, and by far the legal profession is heavily involved here.

That concludes my statements.

MR. STEIN: Thank you.

Are there any comments or questions?

MR. WRIGHT: Mr. Stein.

I heard one figure during your presentation of reduction of 5,000 tons--

PROF. SKOGERBOE: Annually.

MR. WRIGHT: --annually, but I am not sure I know per area. We need some kind of units on that. Is that per acre of--

PROF. SKOGERBOE: No, it was 5,000 tons due to lining those particular sections of canal.

MR. WRIGHT: Approximately how much acreage is involved under the project?

PROF. SKOGERBOE: Well, this canal system we are talking about serves 5,000 acres.

MR. WRIGHT: So it is about 1 ton per acre of irrigated land?

PROF. SKOGERBOE: Right. But I might point out, the salt pickup per acre is more like 8 tons per acre, so we have only made a small dent in the problem.

The point I really wanted to make was, even though the seepage losses are very low in this particular canal system, that we can very easily show economic benefits far exceeding the costs. And frankly, a year or a year and a half ago I didn't think this would be the case. I thought that the seepage losses were so low that we wouldn't be able to show that it was economically beneficial.

MR. WRIGHT: Were you here yesterday when Mr. Boone discussed the improvements that could be obtained from better drainage systems?

PROF. SKOGERBOE: Was that this morning?

MR. WRIGHT: No, it was yesterday.

MR. DICKSTEIN: Yes, it was.

MR. WRIGHT: Was it this morning?

PROF. SKOGERBOE: First thing this morning.

MR. WRIGHT: This morning? Yes, you are right.

PROF. SKOGERBOE: I missed the first few minutes of his presentation, but I heard most of it.

MR. WRIGHT: So if there is 8 tons of pickup per acre in this particular valley at this point in time, could you maybe describe the drainage system that is there now and tell us whether or not an improved drainage system would be effective in--

PROF. SKOGERBOE: Yes.

MR. WRIGHT: --much larger terms than 1 ton per acre?

PROF. SKOGERBOE: Yes. Well, in the proposal we have before EPA at this present time I mentioned going into a combination of irrigation scheduling and tile drainage, and the idea here is to collect the water reaching the groundwater table before it is allowed to pass deeper into the soil profile and then pass over the beds of Mancos shale, which contain crystalline salts and have a high pickup. So you would still have a certain amount of salt pickup, but you would reduce it substantially, we would feel.

But this is only a solution in a part of the valley, not the entire valley. It is a solution for the lower lying lands.

I might make one other point here. To me a salinity control program for Grand Valley is not a matter of lining canals, it is not a matter of irrigation scheduling; it is a matter of an entire package of on-the-farm water management and rehabilitation of the irrigation system and drainage.

MR. WRIGHT: In your experience as a person involved in irrigated agriculture, have you reviewed the Bureau of Reclamation's report presented yesterday and do you feel that their proposed water quality improvement program covers all of those points that you just mentioned?

PROF. SKOGERBOE: Yes. The only study that I maybe didn't see and hear is on the prediction of subsurface return flows. But not wanting to be too laudatory to the Bureau so that they don't slow down on the job here, I do feel that in what I would call a short time they have put together a program which really hits at the heart of salinity control for irrigated agriculture.

MR. WRIGHT: Thank you very much.

PROF. SKOGERBOE: But at the same time I might point out in my discussions with the Bureau I do feel that they are as well aware of the problem of predicting subsurface return flows as I am. They recognize that this information is needed.

MR. STEIN: There is no such thing as a free potshot at the Bureau.

Mr. Maletic.

MR. MALETIC: I would like to answer that question and let him know that, of course, we have been working on this question of subsurface flows. We will be publishing rather sophisticated studies in this area dealing with the movement of water through the unsaturated zone, through the saturated zone, done for and with EPA and San Luis unit, and extended to other areas. And in Vernal we are making a separate study of this problem. Utah State has already done some studies using similar techniques, and these are published and a lot of work is being done in this field.

MR. STEIN: That is right.

MR. MALETIC: And our studies, of course, contemplate evaluating effects of these projects using these models.

MR. STEIN: You are talking about, you know, what is it, a pickup of 8 tons, 7 tons an acre?

PROF. SKOGERBOE: Yes, 8.

MR. STEIN: Eight. And I think if we cut this back on tiles, cut it back 1 ton down to 7, I don't think that we are going to--maybe we are not going to get the pay dirt.

PROF. SKOGERBOE: No.

MR. STEIN: In other words, it seems to me we have got to do a lot better than that if we are really going to come to grips with this problem.

PROF. SKOGERBOE: I feel personally that we should be able to reduce it in half without too much trouble.

May I add one other comment to Mr. Maletic. When I am talking about predicting subsurface return flows, I am aware also of the work they are doing. But as we go into each area and go into a salinity control program, there has got to be a certain amount of evaluation take place in each area. There is only a certain amount of information transfer that can occur from Grand Valley, say, to Ashley Valley or return. So we have to collect this type of information in Grand Valley. As we gain more experience in utilizing some of these models or get a little more sophisticated in our analysis, then we will be able to cut down on the amount of effort when we go into a new region, but we are still going to have to collect a lot of this basic type of data in each region.

MR. STEIN: All right.

Are there any comments?

MR. WRIGHT: Murray, I think one point maybe that we don't want to lose sight of. We are looking at this 8 tons pickup, but from the report I think we need to remember that it indicated to us that 60 percent of the problem is from natural sources, 33 percent manmade. Of the 33 percent that is manmade, 80 percent is concentration and only 20 percent is the pickup.

So even though it looks big, like 8 tons per acre pickup, this is only one particular project and it is really small in comparison to the overall problem.

PROF. SKOGERBOE: Yes. I would take exception to your citations there, though, on these percentages, because how do we really arrive at that figure? We run an input-output model and we say that there is so much tonnage of salt picked up moving through Grand Valley and then we turn around and we divide that total tonnage by the number of acres of irrigated ground, which in this case is about 100,000. And the total annual tonnage picked up is somewhere between 900,000 and 1 million. So from that we come up with maybe 9 or more.

But we don't know of that how much is due to irrigated agriculture and how much is due to natural sources. These breakdowns by percentage that are given in this report for the total Upper Basin don't apply at all to Grand Valley. I mean we are shooting in the dark as to what those percentages are when we talk about Grand Valley. All we really know is the total tonnage of salt that is picked up.

MR. STEIN: Are there any comments or questions?

If not, thank you very much.

PROF. SKOGERBOE: Thank you.

MR. STEIN: We have a communication here from the National Council of Public Land Users, Grand Junction, Colorado.

Without objection, I would like to put this in. I think the major pitch here—you get all kinds of suggestions—is that they recommend the way to clean this up is to recover the Federal public land watershed with a suitable vegetative cover. The first requirement for this would be the complete removal of the original cause--the domestic livestock.

(The above-mentioned letter follows:)

National Council of Public Land Users
P. O. Box 811
Grand Junction, Colorado 81501

Paul Maxwell, President
Herbert Snyder, Secretary

RECEIVED
E.P.A. REGION IX
FEB 11 10 52 AM '72

February 8, 1972

Mr. Curtiss M. Evert
Acting Regional Administrator
U.S. Environmental Protection Agency, Region IX
100 California Street
San Francisco, California 94111

Dear Sir:

Thanks for the report, "The Mineral Quality Problem in the Colorado River Basin", together with Summary Report and Appendices A - D.

Your invitation to attend the meeting to be held February 15 - 17, 1972, at Las Vegas, Nevada is sincerely appreciated. It is apparent we will be unable to attend. However, a copy of the minutes of the meeting would be appreciated.

The National Council of Public Land Users have prepared a resolution pertaining to salinity on the federal public lands watershed, a copy of which is enclosed. This is the only written testimony we are prepared to submit at this time.

Here's hoping for some action, for it is long past due.

Yours truly

Herbert Snyder

Herbert Snyder, Secretary

PS. An extra copy of the resolution is enclosed to be included with the minutes of the meeting.

RESOLUTION PERTAINING TO SALINITY ON THE FEDERAL PUBLIC LANDS WATERSHED

WHEREAS: Reports indicate that ninety (90) per cent of the water flowing in Colorado's streams arises on United States public lands watersheds.

WHEREAS: Research by the U.S. Environmental Protection Agency reveals that much of these federal public lands are highly mineralized with soluble salts.

WHEREAS: Extreme grazing abuse on these federal public lands by domestic livestock has been practiced by an extremely small minority of domestic livestock permittees for scores of years.

WHEREAS: This overgrazing abuse has denuded the federal public lands of natural protective covering vegetation and laid it bare to high temperatures from the sun.

WHEREAS: Evaporation of water from these uncovered lands has resulted in capillary action concentrating mineral salts at the surface of the land.

WHEREAS: Rainfall and melting snow has accumulated these salts in their accelerated runoff, carrying them into the streams.

WHEREAS: Aquatic life, together with other water users, has been depleted and degraded as a result of saline concentration in the stream drainages and reservoirs.

WHEREAS: The runoff waters have been used for many years for purposes of irrigation on lands within the Colorado river drainage.

WHEREAS: The irrigation practice of soaking the irrigated lands, then shutting off the water while evaporation and plant growth take place, has resulted in excessive concentration of salts in these lands. The irrigated lands have been suffering from continual depletion of production since the inception of the practice of irrigation with these saline waters. Much of this once highly productive irrigated land is now practically worthless for agricultural purposes.

WHEREAS: The waters from the Colorado river drainage are of inestimable value and the quality is critical for domestic requirements.

THEREFORE BE IT RESOLVED: That the first effort in improving the quality of the Colorado river water should be the recovering of the federal public land watershed with a suitable vegetative cover. The first requirement for this must be the COMPLETE REMOVAL OF THE ORIGINAL CAUSE - THE DOMESTIC LIVESTOCK. Removal is a necessity because the present condition of the lands demonstrate the incapacity of the livestock users - or the government agencies - to adequately protect the federal public lands. No other program can be administered or expected to be satisfactory.

BE IT FURTHER RESOLVED: That the highly expensive program of desalination by artificial means, such as by desalination machinery, be delayed until the full effects of natural vegetative recovery has had an opportunity to demonstrate its value.

BE IT FURTHER RESOLVED: That specific sources, such as flowing wells, be plugged.

BE IT FURTHER RESOLVED: That present saline levels in the Colorado River watershed have become so high as to require IMMEDIATE ACTION to protect the national health, safety and wellbeing of the citizens.

This resolution regularly adopted at a meeting of the National Council of Public Land Users at Grand Junction, Colorado, February 8, 1972

Attest:

Paul Maxwell

Paul Maxwell, President

Herbert Snyder, Secretary

Dr. H. K. Qashu

MR. STEIN: May we have Dr. H. K. Qashu of the University of Arizona.

HASAN K. QASHU, PH.D.
HYDROLOGY AND WATER RESOURCES
UNIVERSITY OF ARIZONA
TUCSON, ARIZONA

DR. QASHU: Mr. Chairman.

I would like to make a comment, two comments, and they will be short, One on the work being done at this time concerning water and salt movement in soil. There is a working model. John Maletic of the Bureau of Reclamation has it. It was developed jointly by the University of Arizona in Tucson and the University of California at Davis, and if you people are interested in it I am sure John will make it available for you. It considers both salt and water movement in soil.

We have a project funded by the Office of Water Resources Research at the University of Arizona to look at some of the predictive possibilities, given certain soil conditions and certain water quality, how in irrigated agriculture--what to expect in seepage or water flow below the root zones and a three-dimensional type of a model, how does the water and salt flow below the root zone. And this is a 2-year project which started, oh, less than a year ago and will not be completed until next year.

There is to me one important point I think the conference should consider and that is the same point, really, that has been emphasized before. That is the need for one agency to be responsible for planning of the Colorado River Basin, not only planning action programs but also research. There are a lot of resources at institutions in the region that can be used by action agencies, but I think a lot of the duplication can be avoided if the research is directed by one agency and towards satisfying one purpose.

I will have one more comment to make. We have an active program with the U. S. Bureau of Reclamation on Lake Mead which is for developing a model on salinity, trace minerals and biological productivity of the lake. Unfortunately, the report on it will not be available until about June, and it will be released by the Bureau of Reclamation. That was a 2-year study that will be completed this summer.

Mr. Everett, who will follow me, will give you some information, preliminary information, what we have found.

Mr. Stein made a statement this morning, "We would like to know how can we know when to blow the whistle." EPA has done excellent--

MR. STEIN: That was a question, not a statement.

DR. QASHU: Yes. Well, he asked the question and I really would like to address myself to that question because it is a very important one, when to blow the whistle. Because you are talking there about predictability. I mean to know when to blow the whistle, that means you are predicting there is a change going to occur in the system. And whenever we are predicting anything there is uncertainty or risk. If we have data we have a risk, if we don't have data we have uncertainty.

And that would bring us to the range of predictability, how good is that--what is that predictability based on. If you have good data, good basic information, you will be able to do something with certainty; you will be able to say this is going to happen. But if you don't have that, it is like the economic model you have on page 31 of the Summary Report of the EPA. Some of these cost values you have, if you put confidence limits on these values, I assure you they will extend from minus to probably $100 million or more. So the results could be misleading.

EPA has done an excellent job, I feel, in putting the reports together and no doubt the scientific curiosity of us by the reports will result in some effort which will have some impact on the salinity control of the lower Colorado River studies or both, total basin, really, go on up. Although I disagree with some of the conclusions, the research team did a good job, and I do regret the fact that the people who did the job were moved from research to enforcement. As a matter of fact, I would like to suggest to the Chairman to run an impact study on what happens when you transfer people from research to enforcement in EPA. (Laughter.)

MR. STEIN: I don't know what you-- Let me indicate something to you here, and this should be brought out.

Since the first days of the conference, this whole Colorado study and the information you got was financed by enforcement money out of the budget. And we didn't transfer anyone. Our largest single item was for studies, and we financed this for many years at the rate of three-quarters of a million, $750,000 a year.

So I think the professors really should look at this if you want to know where the money is coming from. Don't bite the hand that feeds you. (Laughter.)

DR. QASHU: No, no, no, I am not. I think you misunderstood my comment, Mr. Stein. What I was saying, we had a crew in Denver that was familiar with the institutions in research and they were really--this applies to Bill Blackman, it applies to Jim Russell and all of them who were involved in research with universities.

MR. STEIN: Right, but where do you think their money came from, Professor? That was enforcement money getting those wonderful researchers out to see you.

Again I say, why don't you see how benign we are and how we are helping you out?

DR. QASHU: Well, maybe there is a misunderstanding there. I don't like to stretch it too much.

I believe in all the answers and the discussion we have here there is one important point that has not been discussed and in the 2 days we have failed to discuss it and that is the interaction between salinity, sediments, biological components, and the use of water, that is in situ use of water.

I feel there should be a full consideration given to the ionic species components of salinity when we are talking about salinity because, just to illustrate the point here, salinity of, say, X number of ppm as reported in the reports may generate a different loss function if you will try to develop an economic model than a salinity half that amount or double that amount. What I am saying, if you have salinity of 600 ppm with a majority sodium you are going to have much more harm than if you have 1,000 ppm with a majority of the ions calcium. And this has not been brought out in the conference and this is one of the points which I would like to emphasize, need of research to establish some kind of a range, what is acceptable for what use. And that is why I feel very strongly against a number just pulled from the hat and establishing a standard by saying, "Well, it should not exceed 800 ppm or 600 ppm."

In conclusion I would like to say whoever is going to blow the whistle has my sympathies unless the decision is based on a debated resource plan and a supporting research program to go with it.

Thank you.

MR. STEIN: Thank you.

Any comments or questions?

Ralph Esquerra.

RALPH ESQUERRA
CHAIRMAN
CHEMEHUEVI INDIAN TRIBE
HAWTHORNE, CALIFORNIA

MR. ESQUERRA: The name is Ralph Esquerra.

I am the Chairman of the Chemehuevi Indian Tribe of California. The Chemehuevi--

MR. STEIN: Why don't you spell that for us?

MR. ESQUERRA: Chemehuevi?

MR. STEIN: Yes. C-h-e-m-e-h-u-e-v-i. Right?

MR. ESQUERRA: Yes.

MR. STEIN: O. K.

MR. ESQUERRA: The Chemehuevi Indian Reservation, consisting of some 28,000 acres, is located along the western shoreline of Lake Havasu some 30 miles south of Needles, California. The Chemehuevi Indian Tribe is a member of the newly-formed Federation of River Tribes of the Colorado River, and I am here today to testify on behalf of this entity with respect to the quality of the waters of the Colorado River.

The tribes comprising this federation are the Colorado River Indian tribes, Fort Mohave Tribe, Quechan Tribe, Cocopah Tribe, and the Chemehuevi Indian Tribe. Together these tribes have adjudicated rights to approximately 1 million acre-feet of water in the Colorado River. These rights are decreed in the Supreme Court case of Arizona versus the State of California.

The Federation of the River Tribes of the Colorado River is deeply concerned about the quality of the waters comprising the Colorado River. In the words of the Supreme Court respecting the tribes of the federation, "Colorado River Water is essential to the life of the Indian people." Life cannot be sustained on the American Indian reservations in the Colorado River Basin without good water from the Colorado River or its tributaries.

In the process of reviewing the Environmental Protection Agency's Summary Report on the mineral quality problem on the Colorado River Basin, we have concluded that the survival of our people is in jeopardy. The report clearly indicates that the salt concentrations in the lower Colorado River have exceeded the set limits for municipal, industrial and agriculture uses. The report also indicates that the salinity concentrations will become worse if current water diversion plans are permitted to continue.

The Federation of the River Tribes firmly believes that the mammoth Central Arizona Project is another step toward increasing the salinity of the Colorado River and accordingly respectfully requests that the Environmental Protection Agency do everything within its power to halt the construction of the Central Arizona Project and all other authorized diversion projects until a definitive study can be made relating to the effects that these particular projects will have on the soil concentrations in the Colorado River.

Thank you.

MR. STEIN: Thank you. Are there any comments or questions?

Thank you very much, sir.

Do we have G. Bryant, Fort Yuma Indian Reservation, here?

G. Brown, Quechan Tribe?

Lorne G. Everett of the University of Arizona?

LORNE G. EVERETT
DEPARTMENT OF HYDROLOGY
UNIVERSITY OF ARIZONA
TUCSON, ARIZONA

MR. EVERETT: Mr. Chairman, my name is Lorne Gordon Everett and I come to this meeting in the lowly capacity of a graduate associate at the University of Arizona.

The single thrust of this rather spontaneous talk will be to show the level of sophistication that exists today in the relationship between salinity and biological primaries in the lower Colorado River system. John has chosen to take out of context some of the work that we have been doing on Lake Mead under the cooperation of the Bureau of Reclamation over the past 2 years. What we would like to do is illustrate how we have quantitatively attempted to show the correlation between the biological parameters and salinity.

L. G. Everett

The map on the right-hand side here illustrates the sampling procedure that we established. We chose eight locations across Lake Mead. At these stations we decided to, at six times over the year, look at all of the biological parameters as they existed in one State and correlate them with what we felt was a complete analysis of chemical and hydrodynamic parameters.

I have chosen to take the one parameter that we feel is the most sensitive as a diagnostic indicator of the pollution in Lake Mead. We thought we would take that one indicator and correlate it in a graphical way with salinity.

The bars that appear across the system are established to represent the primary productivity as measured by C^{14} techniques. The green areas are accepted as the ppr rate, primary productivity rate, accepted by Rodhe in Europe and Odum in America. We can see that at no place in the system does Lake Mead behave as an oligotrophic lake.

Now, the purple area represents what we like to call a mesotrophic lake. This is a situation in which because of enrichment, be it natural or artificial, we are getting algal growth rates that are indicators of problems. We can see by looking at the large bars that the majority of the lake acts as a mesotrophic lake. Don't let this be misleading. The tall bars are representative of September values, which are the highest growing rate. The small bars to the right of each of the larger bars are indications of the winter conditions.

The first thing that we should notice is looking at the right-hand side we see a large red bar appearing that there is a high level of algal growth rate in the South Cove area which is a response to nutrient influxes coming down through the Grand Canyon. At this time we are not going to say whether it is because of boat trips, whether it is because of watershed effects. It can't be quantitatively determined. But six times over the year we have determined that there is a high algal growth rate at South Cove.

Following the red lines to the left of the graph, we realize that there is a decrease in the ppr rate, a significant decrease, indicating that the system is growing towards better water quality conditions. As we come into the Boulder Basin area, we quickly realize that we now have a lake within a lake. A whole system behaves as a unit and not, as has previously been assumed, that the Las Vegas Wash area alone was the problem area. In fact we have shown that as you approach Hoover Dam the problem increases.

So that I don't get myself into a corner with the representation by these bars, we have distributed our parameter with depth and that is the bar graph that you see below.

Now, if we are saying that salinity is in some measure a reflection of water quality problems, we would assume that by measuring salinity across the system we could see the reflection in the algal growth rate. The green line at the bottom of the chart indicates a passage of salinity across Lake Mead. It is kind of turned up, unfortunately. Perhaps I can bend it down.

It soon becomes obvious that as we go towards the left we realize an increase in the soluble salts. We also realize a reduction in the primary productivity rate. If we were quick to assume, we could say increased salinity results in poor algal growth. We may say that in a couple of months, but we won't say it at this stage.

As we go into Boulder Basin we see a drop in the salinity and then a slight increase again. So generally you would say salinity doesn't materially increase coming across this lake.

The question has been asked to explain the purple part of the bar again. The purple bar represents the level of primary productivity associated with a mesotrophic lake, which is a lake that is in transitory stage between poor nutrient conditions and excessive nutrient conditions. It might be described as the state of Lake Tahoe as it is now.

In any case, we soon realized that in the Boulder Basin area there is a fantastic increase in primary productivity that is not a function of the salinity that comes into the system. So the first thing we have to conclude is that salinity in no way as a gross lump parameter indicates primary productivity if we are going to say that primary productivity is an indicator of water quality problems.

We did not choose to talk in terms of salinity. We wanted to use the term at this talk. We would much rather have broken it down to show the responses of calcium, sodium, chloride, the breakdown of constituents that result in salinity problems.

As a concluding remark, we would like to say that until a functional relationship has been established between biological processes and those elements that are being lumped as salinity, I think we should hesitate on a control value.

Thank you.

MR.STEIN: Thank you, Mr. Everett.

Are there any comments or questions?

If not, thank you very much.

I believe Mr. Dibble has a comment.

Mr. Dibble.

General Discussion

MR. DIBBLE: Mr. Chairman, it was suggested that I clarify one bit of conversation that went on this morning.

Mr. Kennedy when he was speaking, there were some questions about the values at Parker Dam of water between those that he was speaking of and those that EPA was using in some of their testimony. And it was brought to my attention that these differences were primarily because the two entities were using a different method of calculating the total dissolved solids. It is my understanding that EPA was using the filterable residue method and Metropolitan Water District was using the summer constituents method which automatically, particularly with the higher concentrations, will give a different value. So that there not be any misunderstanding of the discussion this morning, I think part of the difference in the figures was just because they were obtained in a different way.

But going on a little further, I think that illustrates the fact that there is a problem in setting numbers and that is making sure that the numbers are all consistent with each other, and it seems to me that the conference might suggest that in the immediate future the various entities that are involved in monitoring, such as EPA, the USGS, the Bureau of Reclamation and other agencies, get together and try to standardize on the

the figures that they use so that in the future we are not using apples and oranges in the same meeting.

MR. STEIN: I think that point is very well taken. This is one we have arising repeatedly. If we are going to use any kind of numbers, we just have to have the same methodology or else we are in trouble. And I think perhaps--well, we of course will get together and we will have to work very closely with the Department of the Interior on this.

These are all the people I have who indicated they wish to speak. Is there anyone else who has anything to say? Because I think this will conclude the public presentation, and we will just have findings and recommendations.

Hearing no one else, Mr. Thatcher has polled the conferees. The consensus seems to be that we will reconvene at 8:30 a.m. here tomorrow morning. I hope you all live as clean as Mr. Thatcher, so we will be bright eyed and bushy tailed when we get here.(Laughter.)

MR. THATCHER: I didn't say I wasn't going to go out tonight.

MR. STEIN: I know, but you have got that wonderful reserve. (Laughter.)

With that we will stand recessed until--

MR. THATCHER: Mr. Chairman.

MR. STEIN: Yes.

MR. THATCHER: I am not sure I heard you correctly. You are not implying that the summary and conclusions would not be a public presentation?

MR. STEIN: No, not at all.

MR. THATCHER: O. K.

MR. STEIN: Absolutely not. Certainly not. I thought I made this clear, this is open to the public. One of our charms is that we are public. You may not like what you see or what you hear, but at least you can form your own conclusions as to whether we or anyone else are doing our job.

With that we will stand recessed until 8:30 tomorrow morning.

(Whereupon, at 4:15 o'clock an adjournment was taken until 8:30 o'clock, Thursday, February 17, 1972.)

MORNING SESSION

THURSDAY, FEBRUARY 17, 1972

8:30 o'clock

MR. STEIN: The conference is reconvened.

The conferees will now go into executive session. We will have the executive session across the hall. Just keep working on your way toward the back. I would ask just the conferees to come because we are going to have such a large group in there, and hopefully we should be out, optimistically, in a half hour, possibly an hour, but we will let you know when we will be out to make a statement.

...Executive Session...

(The conference reconvened at 9:30 o'clock.)

MR. STEIN: Let's reconvene.

I wish everyone would sit down.

We have discussed two main subjects at the conference. One was the tailings pile problem dealing with the uranium mills. As you recall, the problem of discharges from these mills into the waters has largely been corrected in the region and in the basin, and this has been one of the successes, I think, of the conference and the States and the industries and the AEC. But we still have this residual tailings pile problem and the conferees are in unanimous agreement that a tailings pile regulation comparable to that submitted to the conferees shall be adopted and implemented by the Colorado River States at the earliest practicable date but not later than July 1, 1973.

At this point I would like to call on Mr. Lynn Thatcher of Utah for a statement of a resolution adopted by the States on the salinity problem.

Mr. Thatcher.

MR. THATCHER: Mr. Chairman.

This is the resolution that was developed by the conferees at this session and has been agreed to by the conferees of all the seven States:

WHEREAS, the Colorado River Basin Water Quality Control Project was established as a result of recommendations made at the first session of a joint Federal-State "Conference in the Matter of Pollution of the Interstate Waters of the Colorado River and Its Tributaries," held in January of 1960 under the authority of Section 10 of the Federal Water Pollution Control Act (33 U.S.C. 466 et seq.); and

WHEREAS, in 1963 based upon recommendations of the conferees, the project began detailed studies of the mineral quality problem in the Colorado River Basin; and

WHEREAS, the Environmental Protection Agency transmitted in April 1971 its draft report on "The Mineral Quality

Problem in the Colorado River Basin" to the conferees and water resource agencies of the Colorado River Basin States for review and comment; and

WHEREAS, all Colorado River Basin States reviewed and commented on the draft report on the mineral quality problem in the Colorado River Basin; and

WHEREAS, the Environmental Protection Agency has revised its draft report and transmitted to the Colorado River Basin States a final report dated 1971; and

WHEREAS, the said report constitutes a necessary step toward the solution of the mineral quality problem of the Colorado River system; and

WHEREAS, the States and Federal agencies have implemented measures to control salinity of the Colorado River; and

WHEREAS, the Bureau of Reclamation is authorized to make, and has feasibility investigations under way, to determine additional measures to reduce the salinity of the waters of the Colorado River under present and future conditions; and

WHEREAS, during 1971 the States of the Colorado River Basin urged committees of Congress to appropriate funds to the Bureau of Reclamation to accelerate feasibility investigations of salinity control projects on the Colorado River; and

WHEREAS, additional funds were appropriated to the

Bureau of Reclamation for these feasibility studies; and

WHEREAS, in the interest of comity between the United States and Mexico the State Department has given its support to a basinwide salinity control program:

NOW, THEREFORE, BE IT RESOLVED by the conferees of California, Arizona, Nevada, New Mexico, Colorado, Utah and Wyoming that:

1) a salinity policy be adopted for the Colorado River system that would have as its objective the maintenance of salinity concentrations at or below levels presently found in the lower main stem;

2) in implementing the salinity policy objective for the Colorado River system the salinity problem be treated as a basinwide problem that needs to be solved to maintain Lower Basin water salinity at or below present levels while the Upper Basin continues to develop its compact-apportioned water, recognizing that salinity levels may rise until control measures are made effective;

3) to guard against any rise in salinity the Congress and the Administration be urged to accelerate the entire salinity control program and, in particular, to augment the F.Y. 1973 budgeted amount of $1,005,000; and

4) the Bureau of Reclamation have the primary

responsibility for investigating, planning, and implementing the basinwide salinity control program in the Colorado River system;

5) the Environmental Protection Agency continue its support of the program by a) consulting with and advising the Bureau of Reclamation, b) accelerating its ongoing data collection and research efforts, and c) transferring funds to the Bureau of Reclamation;

6) the Office of Saline Water contribute to the program by assisting the Bureau of Reclamation as required to appraise the practicability of applying desalting techniques; and

7) the adoption of numerical criteria be deferred until the potential effectiveness of Colorado River salinity control measures is better known;

BE IT FURTHER RESOLVED that the Environmental Protection Agency be commended for performing the necessary studies and completing the 1971 report on the Mineral Quality Problem in the Colorado River Basin; and

BE IT FURTHER RESOLVED that copies of this resolution be transmitted to the Secretary of State, Secretary of the Interior, Administrator of the Environmental Protection Agency, Governors and Members of the Congress of the Colorado River

Basin States, the Commissioner of Reclamation, Director of the Office of Saline Water and other interested entities.

That completes the Resolution, Mr. Chairman.

MR. STEIN: Thank you.

Are there any comments?

I would like to ask the Federal conferees. Mr. O'Connell?

MR. O'CONNELL: Yes.

We have reviewed the Resolution of the States and find that we do agree in general and in principle, if not with some of the particular specifics of this unanimous position of the seven States as described in the Resolution you just heard. However, we believe that a more specific and detailed program of action is called for to bring about the reduction of salinity in the Colorado and to implement some of these principles that are enunciated in the Resolution.

We do not have at our disposal today all of the specifics that we would need to identify this particular program of action, but we expect to be with the Bureau of Reclamation and get this information within the next 30 days while the record is kept open, and after reviewing that come up with some specifics of a program of action that we would hope would be also agreed to by the States that would supplement this general statement of principles with which, as I say, we are in general if not specific agreement.

Would that be acceptable, Mr. Chairman?

MR. STEIN: Go on.

Mr. Dickstein.

MR. DICKSTEIN: I once again generally agree in principle with the Resolution and concur with all the comments made by my fellow conferee, Mr. O'Connell.

MR. STEIN: Well, it is my understanding, then, that the States unanimously have agreed on this Resolution. We have previously stated that the record would remain open for 30 days, at the request of various people. It is my further understanding that the Bureau of Reclamation specifically will come up with a document or material in those 30 days which will include proposals for specific reductions of salinity in the Colorado River Basin, in the waters of the Colorado River, and these will be couched in both tonnage or pounds removed and concentrations or either/or, and it will contain proposed time schedules and dates.

And I do think that essentially this is what a conference is all about. The step is to get something cleaned up, and to judge whether we are going to clean it up or not and put everyone on the track. We have to have a time schedule to do the job and have specifics to do the job, and our sister agency, the Bureau of Reclamation, has agreed to come forward with this all-important step in the next 30 days.

However, given the importance of this problem, when we get this material I would suggest that the Federal people, where appropriate, meet with the Bureau and with other Federal agencies to clarify any problems, if there are any problems that may come up, on language or understanding. Also that we get together with the State agencies, or the conferees do that, to be certain there is particular communication. And that we will call another session and reconvene this session of the conference within a few weeks after the 30-day period to make the announcement of the Federal position.

Now, I would expect at that time that the Federal conferees would be prepared to come out with the Federal position for this go-round or session of the conference, is that correct?

MR. O'CONNELL: Yes, we would be in a position to do that.

MR. STEIN: All right.

With that, I think that probably winds up the conference session. There are a couple of announcements I have to make.

Are there any other comments?

MR. THATCHER: Mr. Chairman.

MR. STEIN: Yes.

MR. THATCHER: I have had some questions asked by people who want to submit statements during the 30-day period. What is the appropriate way to address these statements so that they will know?

MR. STEIN: Send them to me as Chairman in Washington, because otherwise you are not going to get them in the record as expeditiously. They will get in there, but it is slower.

Let me again indicate. Obviously, we have a lot of procedures like this, and we have a staff that works full time on putting these documents together. If we get these additional statements in headquarters, then we know what we have and can get them in the record. They will be time stamped, and that will be the most expeditious way to handle it.

MR. THATCHER: All right.

MR. TABOR: Mr. Chairman, although it is understood among the conferees that we all agree with the statement that was read by Mr. Thatcher, I think for the record there should be a roll call of the States and have each member say that he concurs with the statement as presented by Mr. Thatcher.

MR. STEIN: O. K., we will do that. Let me go off the record.

(Off the record.)

MR. STEIN: Let's have the roll call of the States. Will you start?

MR..TABOR: Arizona yes.

MR. DIBBLE: California also concurs, Mr. Chairman. I think while commenting, though, we should point out that this is a big step forward in trying to protect and improve the quality of the Colorado River to have all the States and EPA recognizing that we need a vastly accelerated salinity control program, and personally I am glad to see the progress we have made.

MR. ROZICH: Colorado concurs.

MR. WESTERGARD: Nevada concurs.

MR. WRIGHT: New Mexico concurs.

MR. THATCHER: Utah concurs.

MR. WILLIAMSON: Wyoming concurs.

MR. STEIN: Well, I would like to again thank the States and the other participants in the conference. I do think that we really have achieved something here in, one, developing a record ofi setting forth the problems and coming up with what I hope will be unanimous concerted action by the Federal Government and the State agencies in dealing with this problem. And I really want to say this because I think possibly this has been one of the most significant achievements in water resource development and water quality that we possibly have had in the country, The reason for this is that obviously in a complicated situation like this, as in many other situations in our country, not everyone agrees with the same philosophic principles or theories, and so forth and so on.

But the genius of our country is that in proceedings of this type we can always work out a solution or a mode of operation on a particular problem and go forward. And with all the States involved here and the complicated issues of water rights in this particular section of the country, the fact that we were able to apply that typically American technique of coming forward with an accommodation and moving forward to a solution I think is something that I would like to commend the entire group on.

Before we recess--notice I am saying recess, because we are going to have another session or the concluding session part of this conference after the 30-day period--we will expect, as I understand it, to have the press here at 10 o'clock. It has been our practice--and I think this has worked successfully in the past--that we just recess the conference, and any of you who want to stay with the press, handle this in your own way and do this individually. I think that has worked a lot better and erases any possible inhibitions from anyone, because you are not at the table any more and can say just what you want to say.

With that, if there is nothing more, again I would like to thank you all.

The conference stands recessed until it is called again by the Chairman.

(Whereupon, at 9:45 o'clock, the seventh session of this conference was recessed until further notice.)

SOUTHEASTERN COLORADO
Water Conservancy District
LEGAL AGENCY FOR
FRY-ARK
WATER PROJECT
PHONE 544-2040 • P.O. BOX 440 • 905 HIWAY 50 WEST • PUEBLO, COLORADO 81002

February 23, 1972

Mr. Murray Stein, Chairman
Federal State Enforcement Conference
Environmental Protection Agency
Washington, D.C. 20460

Dear Mr. Stein:

I am sorry it was not possible for a representative from the Southeastern Colorado Water Conservancy District to appear before your Conference in Las Vegas, February 15 - 17, at which time you thoroughly researched the subject "The Mineral Quality Problem in the Colorado River Basin".

Our Conservancy District does have a very keen interest in the work you and your associates are doing in the study of salinity conditions on the Colorado River, and we respectfully request permission to have the enclosed Statement made a part of your Conference Report. We stand ready to gather additional and more specific data upon your request, and should you elect to hold further Hearings, we would like very much to be in attendance.

Very sincerely,

Charles L Thomson

Charles L. Thomson
General Manager

CLT/mb

cc: Honorable John A. Love, Governor, State of Colorado
Honorable Gordon Allott, United States Senator
Honorable Peter H. Dominick, United States Senator
Honorable Wayne Aspinall, United States Representative
Honorable Frank E. Evans, United States Representative
Honorable Donald Brotzman, United States Representative
Honorable Mike McKevitt, United States Representative
Board of Directors, Southeastern Colorado Water Conservancy District

enclosure

POLICY STATEMENT

SOUTHEASTERN COLORADO WATER CONSERVANCY DISTRICT

ON

"THE MINERAL QUALITY PROBLEM IN THE COLORADO RIVER BASIN"

The Board of Directors of the Southeastern Colorado Water Conservancy District, a legal agency in the State of Colorado, established April 29, 1958, under Section 150-5-1, Article 5, WATER CONSERVANCY DISTRICTS - CRS 1963, voted unanimously on Thursday, February 17, 1972, that the following be submitted to the Environmental Protection Agency for consideration as a part of the Testimony taken at the Public Hearing in Las Vegas, Nevada, February 15 - 17, 1972, regarding "The Mineral Quality Problem in the Colorado River Basin". The District is the holder of conditional water decrees on the Colorado River, as a part of the Fryingpan-Arkansas Project, now under construction by the U. S. Bureau of Reclamation, and, consequently, the District has a vital interest in the final results of efforts to establish Salinity Standards on the Colorado River.

The Fryingpan-Arkansas Project was authorized by an Act of Congress, approved August 16, 1962, (76 Stat. 389). The Public Works proposed to be constructed are set forth in House Document 187, 83rd Congress, modified as proposed in the September 1959 Report of the U. S. Bureau of Reclamation entitled "Ruedi Dam and Reservoir, Colorado", House Document 353, 86th Congress, 2nd Session. Initial construction on the Project began July 15, 1964, and as of February 1, 1972, the Project was 36%

complete. President Richard M. Nixon has recommended a budget for FY 1973 of $38,515,000.00 for continued construction, and the awarding of two new contracts.

Representatives from the District participated in the drafting of Statements submitted at the Las Vegas Hearing by the Colorado Association of Commerce and Industry, the Seven Colorado River Basin States and the State of Colorado, and we endorse the recommendations offered for consideration by the Environmental Protection Agency. We know each of the above mentioned Statements reflect the sincere and expert opinion of those who will be affected by such Standards as may be promulgated.

The Southeastern Colorado Water Conservancy District is in the unique position of being a holder of conditional decrees on the Colorado River, and, at the same time is an integral part of the Arkansas River Basin. We, therefore, carry additional responsibilities over and above others who participated in the Las Vegas Hearings. Three years ago the Honorable John A. Love, Governor, State of Colorado, appointed four representatives from the District, and the Executive Director of the Department of Natural Resources for the State, to represent Colorado on the Arkansas River Basin Interstate Committee. This Committee consists of five appointees from each of the States served by the Arkansas River, namely, Arkansas, Oklahoma, Kansas and Colorado, and has the responsibility of studying the Arkansas River from its origin in our District in Colorado, to its confluence with the Mississippi River. Consequently, we are aware of Salinity Studies which the Environmental Protection Agency has conducted in the Arkansas and Red River Basins; the United States Bureau of Reclamation in the Colorado River Basin; and by the Office of Saline Water in the Arkansas River Basin in Colorado, and the Pacific Coast; and do recommend that all data and conclusions developed in said Studies be made an integral part of such Standards as may be established for the Colorado River Basin.

We sincerely urge that consideration be given to the fact economies have been established in both the Colorado and Arkansas River Basins, predicated upon water supplies available, and respectfully suggest that final Standards be set to not reduce the absolute need for use and successive use of the waters historically and beneficially used. We recognize that, thanks to Agencies such as the Environmental Protection Agency, technology to relieve salinity problems from successive uses of water has accelerated at a rapid rate, in order that the problem can be arrested. Such technology, however, has not brought complete solutions at this time, and the expensive equipment is still almost prohibitive to existing water users in each Basin. We also urge that careful consideration be given to the natural causes of salinity when considering technology to resolve the total problem. It is essential, therefore, that Federal funds be made available to meet such Standards as may hereafter be established by the Environmental Protection Agency. This is in conformity with legislation now pending before Committees of Congress of the United States.

The District strongly endorses those particular sections of the CACI and Colorado River Basin Statements, calling attention to the fact salinity problems on the Colorado River are of Interstate and International character, and, consequently, the solutions are properly a responsibility of the United States. Federal funds for equipment, operation and maintenance to resolve the problem should be made available when Standards are established. We highly commend the Environmental Protection Agency for the procedure being followed to research this complex Nationwide program, and offer the services of our District in arriving at a fair and equitable solution in the public interest.

QUALITY OF WATER
COLORADO RIVER BASIN

PROGRESS REPORT No. 5

JANUARY 1971

UNITED STATES
DEPARTMENT OF THE INTERIOR

United States Department of the Interior

OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

JAN 12 1971

Dear Mr. Speaker:

Transmitted herewith is the biennial report (Progress Report No. 5 dated January 1971) on continuing studies of the quality of water of the Colorado River Basin. The report is transmitted pursuant to Section 15 of the Act of April 11, 1956 (70 Stat. 105), authorizing the Colorado River Storage Project and Participating Projects; Section 15 of the Act of June 13, 1962 (76 Stat. 96), authorizing the Navajo Indian Irrigation Project and the initial stage of the San Juan-Chama Reclamation Project; and Section 6 of the Act of August 16, 1962 (76 Stat. 102), authorizing the Fryingpan-Arkansas Project.

Sincerely yours,

Assistant Secretary of the Interior

Speaker of the House
of Representatives
Washington, D. C. 20515

IDENTICAL LETTER TO:

Hon. Spiro Agnew
President of the Senate
Washington, D. C. 20510

Enclosure

QUALITY OF WATER
COLORADO RIVER BASIN

PROGRESS REPORT No. 5

JANUARY 1971

MARCH 3, 1849

UNITED STATES
DEPARTMENT OF THE INTERIOR

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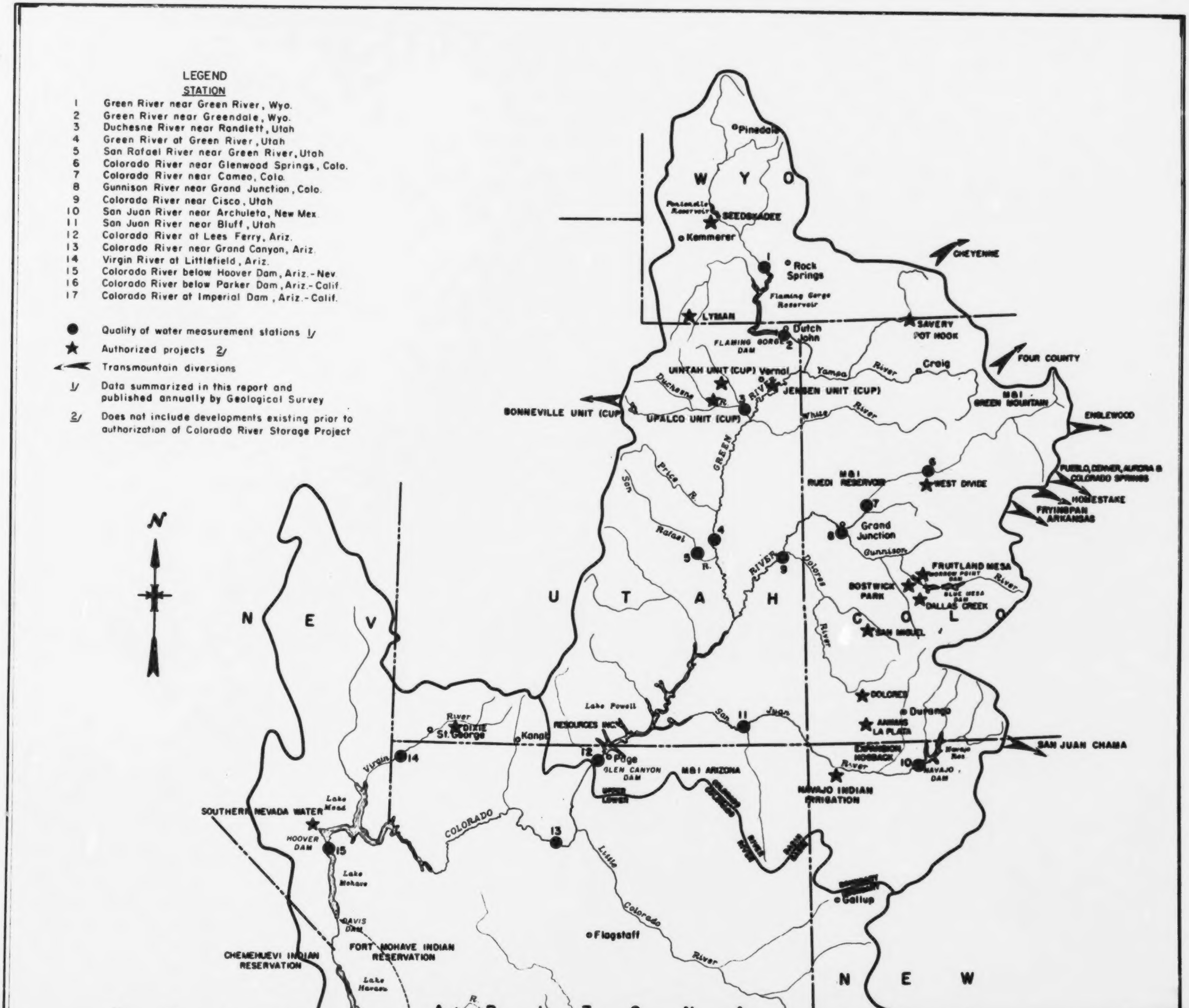
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STATION
1 Green River near Green River, Wyo.
2 Green River near Greendale, Wyo.
3 Duchesne River near Randlett, Utah
4 Green River at Green River, Utah
5 San Rafael River near Green River, Utah
6 Colorado River near Glenwood Springs, Colo.
7 Colorado River near Cameo, Colo.
8 Gunnison River near Grand Junction, Colo.
9 Colorado River near Cisco, Utah
10 San Juan River near Archuleta, New Mex.
11 San Juan River near Bluff, Utah
12 Colorado River at Lees Ferry, Ariz.
13 Colorado River near Grand Canyon, Ariz.
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15 Colorado River below Hoover Dam, Ariz.-Nev.
16 Colorado River below Parker Dam, Ariz.-Calif.
17 Colorado River at Imperial Dam, Ariz.-Calif.
● Quality of water measurement stations 1/
★ Authorized projects 2/
Transmountain diversions
1/ Data summarized in this report and published annually by Geological Survey
2/ Does not include developments existing prior to authorization of Colorado River Storage Project
N
W Y O
Pinedale
SEEDSKADEE
Kemmerer
Rock Springs
Flaming Gorge Reservoir
LYMAN
CHEYENNE
SAVERY POT HOOK
Dutch John
FLAMING GORGE DAM
FOUR COUNTY
Craig
Yampa River
UINTAH UNIT (CUP)
Vernal
JENSEN UNIT (CUP)
Duchesne R.
GREEN RIVER
M&I GREEN MOUNTAIN
ENGLEWOOD
BONNEVILLE UNIT (CUP)
UPALCO UNIT (CUP)
White River
M&I RUEDI RESERVOIR
WEST DIVIDE
PUEBLO, DENVER, AURORA & COLORADO SPRINGS
HOMESTAKE
FRYINGPAN ARKANSAS
Price R.
San Rafael R.
Grand Junction
Gunnison River
FRUITLAND MESA
BOSTWICK PARK
DALLAS CREEK
Dolores River
U T A H
C O L O
SAN MIGUEL
N E V
DOLORES
Durango
ANIMAS LA PLATA
Lake Powell
San Juan
RESOURCES INC.
St. George
DIXIE
Virgin River
Kanab
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M&I ARIZONA
EXPANSION HOGBACK
SAN JUAN CHAMA
NAVAJO DAM
Navajo Res.
NAVAJO INDIAN IRRIGATION
Lake Mead
SOUTHERN NEVADA WATER
HOOVER DAM
COLORADO
Lake Mohave
DAVIS DAM
Little Colorado River
Gallup
Flagstaff
CHEMEHUEVI INDIAN RESERVATION
FORT MOHAVE INDIAN RESERVATION
Lake Havasu
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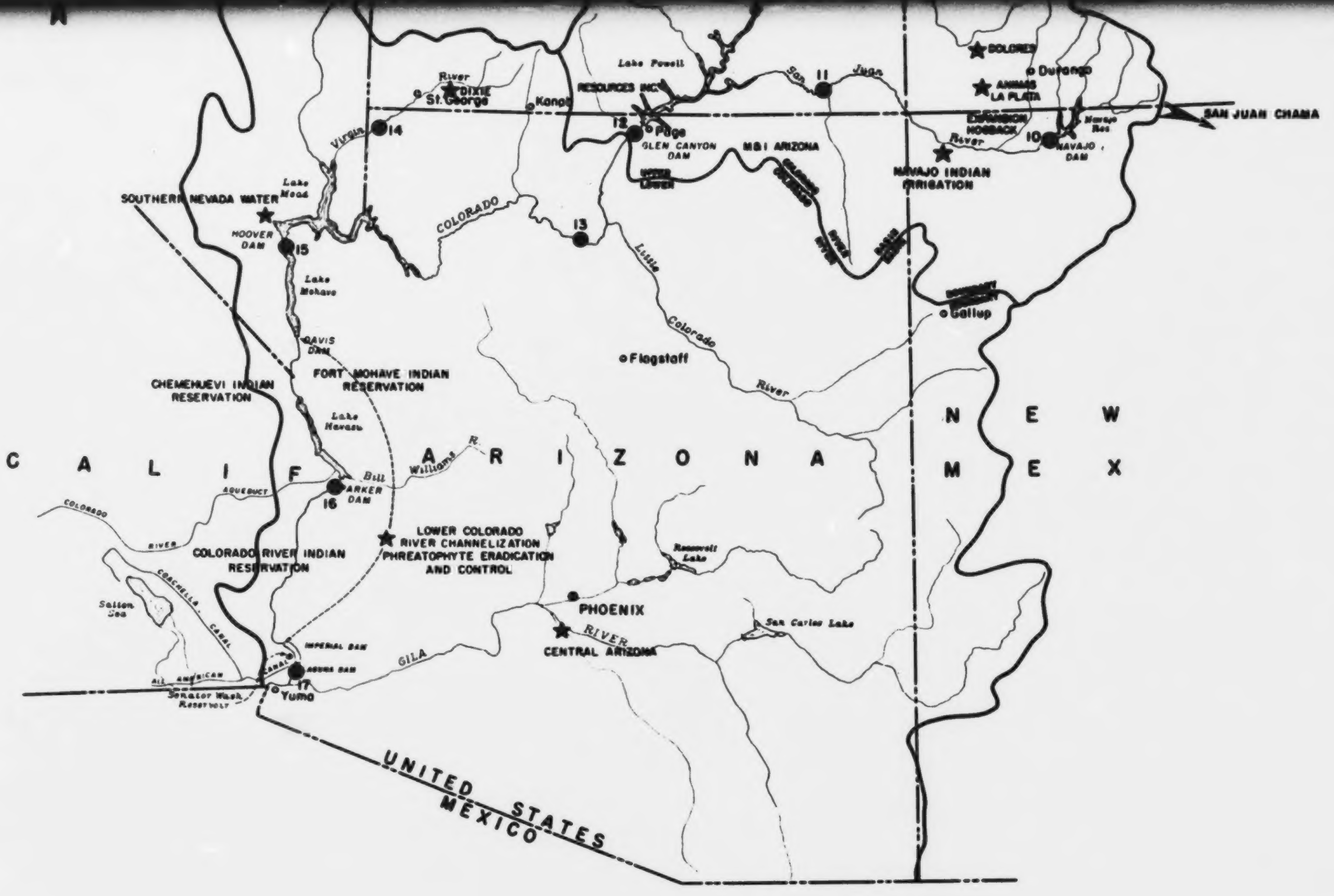
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PHOENIX
RIVER
CENTRAL ARIZONA
San Carlos Lake
Salton Sea
COACHELLA CANAL
IMPERIAL DAM
LAGUNA DAM
GILA
CANAL
17
Yuma
ALL AMERICAN
Senator Wash Reservoir
UNITED STATES
MEXICO

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

COLORADO RIVER BASIN

QUALITY OF WATER MAP

25 0 25 50 75 100 125 150
SCALE OF MILES

65-400-70

JULY 17, 1962
REVISED OCTOBER 1970

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FIGURE 1

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QUALITY OF WATER
COLORADO RIVER BASIN
PROGRESS REPORT

SUMMARY

This report presents the past, the present modified, and the future quality of water of the Colorado River down to Imperial Dam. The past is represented by a tabulation of the recorded or estimated historic condition at 17 quality of water stations for the 1941-68 period. The present modified condition includes adjustments of the historic condition based on the assumption that new developments completed during the 1941-68 period were in operation for the full period. The future quality condition is an estimate of the situation after the presently authorized developments and some projects proposed for authorization are placed in operation. These effects are primarily related to mineral quality although other quality factors are discussed in the report.

Studies of chemical trends indicate that under historic conditions the average concentration of dissolved solids of the Colorado River at Lees Ferry had about 0.75 ton per acre-foot, below Hoover Dam about 0.94 ton per acre-foot, and at Imperial Dam about 1.02 tons per acre-foot for the 1941-68 period.

Under present modified conditions (that is assuming that the recently constructed projects were in operation for the entire period) the concentrations would have been about 0.84, 1.03, and 1.18 tons per acre-foot, respectively, at the three stations.

It has been assumed for purposes of this study that the rate of pickup of dissolved solids from new irrigated lands would vary from zero to 2 tons per acre. It was also assumed no additional pickup of dissolved solids would occur for lands already under irrigation.

Under future conditions, assuming negligible salinity control measures, with all authorized projects and projects proposed for authorization in operation and with an assumed pickup of 2 tons per acre on the new irrigated lands, the concentrations are estimated to be 1.09 tons per acre-foot at Lees Ferry, 1.38 tons per acre-foot below Hoover Dam, and 1.70 tons per acre-foot at Imperial Dam.

The depletions used in this report for the projects, both authorized and proposed for authorization together with present developments and other proposals, are estimated to be the ultimate depletions for the developments listed. Other developments, as yet not identifiable, are expected to occur which will reduce the quantities of water shown for the various stations and cause some changes in concentrations from those indicated in this report.

SUMMARY

This report also includes discussions of the effects of salinity on water uses and potentials for salinity control measures within the basin.

Other water quality aspects including sources of pollution and parameters other than salinity are discussed. These parameters include sediment, dissolved oxygen, temperature, pH, heavy metals, toxic materials, nutrients, bacteria, and radioactivity.

PART I. INTRODUCTION

A. Legislative Requirements for Report

This is the fifth progress report on Quality of Water in the Colorado River Basin. The directive for preparing this and the four previous reports is contained in three separate public laws. Section 15 of the authorizing legislation for the Colorado River Storage Project and participating projects, Public Law 485, 84th Congress, Second Session, April 11, 1956, states, "The Secretary of the Interior is directed to continue studies and make a report to the Congress and to the States of the Colorado River Basin on the quality of water of the Colorado River."

A progress report to comply with Public Law 84-485 was in preparation when the authorizing legislation for the San Juan-Chama Project and the Navajo Indian Irrigation Project (P.L. 87-483) became effective on June 13, 1962. Section 15 of this act states, "The Secretary of the Interior is directed to continue his studies of the quality of water of the Colorado River system, to appraise its suitability for municipal, domestic, and industrial use and for irrigation in the various areas in the United States in which it is used or proposed to be used, to estimate the effect of additional developments involving its storage and use (whether heretofore authorized or contemplated for authorization) on the remaining water available for use in the United States, to study all possible means of improving the quality of such water and of alleviating the ill effects of water of poor quality, and to report the results of his studies and estimates to the Eighty-Seventh Congress and every two years thereafter."

A few weeks later Public Law 590, 87th Congress, Second Session, which authorized the Fryingpan-Arkansas Project, was passed with a similar section pertaining to quality of water reports. This public law, however, stipulated that January 3, 1963, would be the submission date for the initial report and that the reports should be submitted every 2 years thereafter.

B. Previous Reports

The January 1963 report prepared by the Department of the Interior was comprised of two parts: (1) an assessment of the water quality situation in the part of the Colorado River Basin above Lee Ferry, Arizona, as of 1957, prepared by the Geological Survey; and (2) a projection of the water quality effects to be expected from additional developments that involve storage and irrigation use of river waters above Lee Ferry by the Bureau of Reclamation.

INTRODUCTION

The January 1965 report appraised the water quality conditions in the Colorado River Basin above Imperial Dam using the period 1941-61 as a base and included data from two points not considered in the 1963 report. The 1967 report included 3 additional years of record and included suspended sediment data for six stations.

Changes made in the January 1969 Progress Report included (1) consideration of the Hammond Project under present modified conditions, (2) an average of about 9,000 acre-feet of water now being used by Cheyenne, Wyoming, (3) the addition of another key station, Colorado River near Glenwood Springs, (4) the net future effects of Upper Colorado River Storage Unit operations being limited to evaporation only, (5) elimination of the Marble Canyon Project, (6) addition of the Central Arizona Project by pumping, (7) addition of the Fort Mohave and Chemehuevi Indian lands, and (8) addition of the Colorado River Indian Project. Other additions included 2 more years of record through 1966, discussions of state water quality standards, industrial wastes, municipal problems, temperature data, and salinity control.

Following, in addition to including 2 more years of record, are changes which have occurred since completion of the January 1969 report and which are incorporated in this report: (1) showing present modified flows and corresponding dissolved solids only on a mean annual basis (1941-68) rather than on a year-by-year, month-by-month basis; (2) eliminating the Green River near Ouray, Utah, station; (3) considering Silt and Emery County Projects as existing rather than future projects; (4) including estimated average reservoir evaporation losses not reflected in historic records as a part of present modified flows; (5) showing only "Historical, Present Modified, and Future" conditions on the Summary Table No. 18; and (6) addition of discussions of agricultural wastes, mine drainage, dissolved oxygen, pH, toxic materials including pesticides, heavy metals, nutrients, and radioactivity.

In order to keep each report self-contained, it has been necessary to include some of the text material and tables from these previous reports in this fifth progress report dated January 1971.

C. Cooperation

This report was prepared by the Bureau of Reclamation with assistance of the Geological Survey and Federal Water Quality Administration. The Geological Survey provided most of the basic data and prepared some of the sections of "Basic Studies." A continuing cooperative program between the Bureau of Reclamation and the Survey for the collection of streamflow quality data and the exchange of information has been in effect for a number of years. This cooperation provides for the collection of data at stations other than those normally maintained by the Survey. The Federal Water Quality Administration who collects samples where needed in areas not covered by the Geological Survey or Bureau of Reclamation has also participated extensively in preparing this report. Data collected by the Metropolitan Water District of Southern California have also been included in this report.

Below Hoover Dam, water quality along the main stem of the river is determined by analyzing daily samples taken at key stations. Data obtained above each project diversion and below the return flow from each project show the effect of irrigation on water quality in each section of the river. Data are obtained periodically at various points along the river and in drains in cooperation with the Geological Survey, the Colorado River Indian Agency, the Metropolitan Water District of Southern California, the Imperial Irrigation District, and others.

D. Scope

This report presents data concerning (1) the historical quantity and quality of the flows of the Colorado River and its principal tributaries for the 1941-68 period; (2) an evaluation of historical conditions modified to reflect present development; and (3) a projection of the range of salinity conditions resulting from future development at 17 selected stations in the basin. The potential for salinity control and the current status of salinity control activities are also discussed. A section of the report is devoted to water quality parameters other than salinity.

E. Water Quality Legislation

In addition to the legislative requirements previously discussed for studies of water quality in the Colorado River Basin, other legislation authorizes the Secretary of the Interior to conduct various activities directed toward the protection and enhancement of water quality.

The Federal Water Pollution Act, P.L. 84-660, as amended (P.L. 87-88, P.L. 89-234, P.L. 89-753, and P.L. 90-224), established a national policy of water quality enhancement through the prevention, control, and abatement of water pollution. The Secretary is directed by the act to cooperate with other Federal and State agencies as well as involve municipalities and industries in the development of comprehensive programs aimed at reducing the water quality degradation in interstate streams and associated tributaries.

The Water Quality Act of 1965 amended the Federal Water Pollution Control Act to require the establishment of water quality standards for all interstate waters. These standards were to consist of water quality criteria and a plan for implementation and enforcement of the criteria. Establishment of such standards was thus required for the Colorado River and its interstate tributaries.

INTRODUCTION

Each of the seven Basin States proceeded with actions directed toward establishment of standards for the Colorado River. Early in the standards-setting process, it became apparent to the states that, because of legal and institutional constraints combined with lack of technical knowledge on salinity control and management, it would be very difficult to establish numerical salinity standards which would be workable, equitable, and enforceable.

The seven Basin States subsequently developed water quality standards which did not include salinity standards and submitted these standards to the Secretary for review and approval. Following a period of review and negotiations with the states in an attempt to establish suitable numerical salinity standards, former Secretary of the Interior Stewart Udall reached a decision on approval of the proposed standards. In recognition of the problems associated with establishing numerical standards, the Secretary approved the proposed standards with the understanding that suitable numerical criteria would be established by the states at some future date when sufficient information on which to base such criteria had been developed. The states have taken no further formal action to establish numerical salinity standards. A number of the investigations reported herein have been undertaken to improve the technical knowledge of salinity control and provide part of the basis on which suitable standards could be established.

Beginning in 1960 six of the seven states of the basin have met in eight conferences to discuss water quality problems. Three of these conferences have been of a technical nature dealing with specific pollution sources and problems. Initially, the conferences were primarily concerned with pollution from radioactive sources, but from 1963 to the present the emphasis has been directed more toward salinity problems of the basin. Five of the conferences have considered this water quality problem.

In the second technical conference in February 1964 the state conferees assigned the Colorado River Basin Water Quality Control Project of the U.S. Public Health Service in Denver, Colorado, the following general objectives:

(1) Assess the nature and magnitude of the salinity problem in the Colorado River system,

(2) Evaluate feasible methods of control and salt-load reduction in the river, and

(3) Determine net basinwide economic benefits associated with various levels of salinity control.

The Federal Water Quality Administration has concluded the studies begun by the Public Health Service to meet these objectives.

PART II. DESCRIPTION OF BASIN

A. Geology

The upper or northern portion of the Colorado River Basin in Wyoming and Colorado is a mountainous plateau 5,000 to 8,000 feet in elevation marked by broad, rolling valleys, deep canyons, and intersecting mountain ranges. Hundreds of peaks in these mountain chains rise to more than 13,000 feet above sea level and many exceed 14,000 feet in elevation. Mountain lakes exist in considerable numbers. The southern portion of the Upper Basin is studded with rugged mountain peaks interspersed with broad, alluvial valleys and rolling plateaus. The main stream and its tributaries in Colorado generally flow in deep mountain canyons. The Green River, primary tributary of the Colorado River, flows in similar canyons in Wyoming, Colorado, and Utah after rising in the Wind River Mountains. The San Juan River, a large tributary, emerges from the mountains of southwestern Colorado, flows through northwestern New Mexico, and then traverses the deep canyons of the San Juan in Utah before joining the Colorado River in Glen Canyon. The Glen Canyon section of the main stream and tributaries lies almost entirely in deep canyons.

Rocks of all ages from those of the Archean age (the oldest known geological period) to the recent alluvial deposits, including igneous, sedimentary, and metamorphic types, are found in the Colorado River Basin. The high Rocky Mountains which dominate the topography of the upper regions are composed of granites, schists, gneisses, lava, and sharply folded sedimentary rocks of limestone, sandstone, and shale. Many periods of deposition, erosion, and upheaval have played a part in the present structure of these mountains.

In contrast to the folded rocks of the mountains which fringe the basin, the plateau country of southwestern Wyoming, eastern Utah, and northern Arizona is composed principally of horizontal strata of sedimentary rocks. Slow but constant elevation of the land area has allowed the Colorado River and its tributaries to cut narrow, deep canyons into the flat-topped mesas. This type of erosion reaches its culmination in the Grand Canyon where the Colorado River has cut through all of the sedimentary rocks down to the oldest Archean granites.

The Lower Basin is characterized by broad, flat valleys separated by low ranges. These valleys are filled by large accumulations of alluvial deposits.

Sediment removed by constant erosion of the upper areas was deposited in Arizona, California, and Mexico and now forms the great delta of the Colorado River.

Reservoirs constructed above Lee Ferry (Lake Powell, Flaming Gorge, Fontenelle, Navajo, Morrow Point, and Blue Mesa), together with Lake Mead downstream, have caused some major changes in stream regimen: (1) The stream channels inundated by these reservoirs will no longer be subjected to natural stream erosion, (2) the accumulation of sediment and water within the reservoirs slows the growth and flooding of the Colorado River delta, (3) flooding has diminished in many areas, and (4) sections of sediment-laden streams have given way to clear water streams and lakes.

The mineral concentration in runoff increases from the headwater areas downstream and occurs in relation to the geologic character of the terrain across which the Colorado River and its tributaries flow. The geologic formations that largely contribute to the mineral concentrations in natural runoff are evaporites of Paleozoic age, shale of Cretaceous age, and salt and gypsum of Tertiary age.

B. Soils

The soils of the Colorado River Basin closely resemble the geologic formations of their origin. Only in limited areas at the higher elevations has the precipitation leached the soil mass of its soluble constituents. Over most of the area both residual and transported soils are basic in reaction and well supplied with carbonates with normal or mature soils exhibiting a distinct horizon of carbonate accumulation. The impress of soil-forming factors has resulted in the widespread development of soils classified as members of the Gray-Desert Great Soil Group. In areas with higher rainfall, soils of the Brown and Chestnut Great Soil Groups have developed. Saline and alkali (sodic) soils occur in many parts of the basin.

The residual soils comprise the larger area and are usually shallow in depth over shale and sandstone of various ages. Many of the shales are saline but contain much gypsum as well as other chloride and sulphate salts. Some formations are high in sodium chloride and some have sodium carbonate or bicarbonate strata. Very few residual soil areas are suitable for irrigation development.

The alluvial materials are extremely variable and range from alluvial fans and terraces, outwash plains, to lacustrine sediments. Some areas have soils from material transported only short distances and resemble the original materials. Other areas have soils which have been transported and mixed extremely well. Most of the agricultural areas are on these well-mixed alluviums and, therefore, the soils are quite variable.

Extensive areas of Eolian deposits occur in parts of the basin, principally in southwestern Colorado. The uniformly textured soils are reddish brown in color and have no resemblance to either the underlying formations or adjacent areas. These are excellent agricultural soils, but in many areas topography makes agriculture difficult.

C. Climate

The Colorado River Basin has climatic extremes, ranging between year-round snow cover and heavy precipitation on the high peaks of the Rocky Mountains to desert conditions with very little rain in the southern part of the basin. This wide range of climate is caused by differences in altitude, latitude, and by the configuration of the high mountain ranges. The encircling mountain ranges obstruct and deflect the air masses to such an extent that storm patterns are more erratic than in most other parts of the United States. Most of the moisture for precipitation on the Upper Basin is derived from the Pacific Ocean and the Gulf of Mexico. The Pacific source predominates generally from October through April and the Gulf source during the late spring and early summer.

In the northern part of the basin most precipitation falls in the form of winter snows and spring rains. Summer storms are infrequent but are sometimes of cloudburst intensity in localized areas. In the more arid southern portion the principal rainy season is in the winter months with occasional localized cloudbursts in the summer and fall.

Extremes of temperature in the basin range from 50° F. below zero to 130° F. above zero. The northern portion of the basin is characterized by short, warm summers and long, cold winters, and many mountain areas are blanketed by deep snow all winter. The southern portion of the basin has long, hot summers, practically continuous sunshine, and almost complete absence of freezing temperatures.

Nevertheless, the entire basin is arid except in the extremely high altitudes of the headwaters areas. Rainfall averages as low as 2.5 inches in the southern end of the basin while total precipitation in the high mountains may range from 40 to 60 inches annually.

D. Vegetation

Areas of higher elevation are covered with forests of pine, fir, spruce, and silver-stemmed aspens, broken by small glades and mountain meadows. Pinon and juniper trees, interspersed with scrub oak, mountain mahogany, rabbit brush, bunch grasses, and similar plants grow in the intermediate elevations of the mesa and plateau regions. Large areas in the Upper Basin are dominated by big sagebrush and related vegetation. Many of the streams are bordered by cottonwoods, willows, and salt cedar.

Scattered cottonwoods and chokecherries grow in the canyons with the cliff rose, the redbud, and blue columbine. A profusion of wildflowers carpets many mountain parks. At lower elevations large areas are almost completely devoid of plant life while other sections are sprinkled with desert shrubs, Joshua trees, other Yucca plants, and saguaro cacti, some of the latter giant plants reaching 40 feet in height. Occasionally, cottonwoods or desert willows are found along desert streams with mesquite and creosote bush or catclaw and paloverde. In recent years many river channels have been overrun with tamarisk or salt cedar to the extent that a large volume of water is being consumed by such vegetation. Measures are being taken to curb the growth of phreatophytes to conserve water.

E. Hydrology

The Colorado River begins where peaks rise more than 14,000 feet high in the northwest portion of Colorado's Rocky Mountain National Park, 70 miles northwest of Denver. It meanders southwest for 640 miles through the Upper Basin to Lee Ferry. The Green River, its major tributary, rises in western Wyoming and discharges into the Colorado River in southeastern Utah--730 river miles south of its origin and 220 miles above Lee Ferry. The Green River drains 70 percent more area than the Colorado River above their junction but produces only about three-fourths as much water. The Gunnison and the San Juan are the other principal tributaries of the Upper Colorado River.

The flows of the San Juan River are now controlled by the Navajo Dam, the Green River by Fontenelle and Flaming Gorge Dams, and the Gunnison River by the Curecanti Unit Dams. Glen Canyon Dam is the only major dam on the main stem of the Colorado above Lee Ferry, but it will permit control of almost all flows leaving the Upper Basin.

The flow at various points in streams in the Colorado River Basin for the 1941-68 period is given in Tables 1 through 17. The records of flow depict the characteristic wide fluctuations from month-to-month and the considerable variation from year-to-year. The recently constructed storage reservoirs will now level out some of these fluctuations.

The natural drainage area of the lower Colorado River below Lee Ferry and above Imperial Dam is about 75,100 square miles. This section of the river is now largely controlled by a series of storage and diversion dams starting with Hoover Dam and ending at Imperial Dam.

At the present time there is no significant storage on the main river or on the tributaries between Glen Canyon Dam and Lake Mead. The intervening tributary inflow is erratic but amounts to almost enough to offset the evaporation from Lake Mead.

DESCRIPTION OF BASIN

Lake Mead provides most of the storage and regulation in the Lower Colorado River Basin with the water being stored for irrigation and municipal and industrial uses, generation of electrical power, and other beneficial uses.

Lake Mohave, the reservoir formed by Davis Dam, backs water at high stages about 67 miles upstream to the tailrace of Hoover Powerplant. Storage in Lake Mohave is used for some reregulation of releases from Hoover Dam, for meeting treaty requirements with Mexico, and for developing power head for the production of electrical energy at Davis Powerplant.

The river flows through a natural channel for about 10 miles below Davis Dam at which point the river enters the broad Mohave Valley 33 miles above the upper end of Lake Havasu.

Lake Havasu backs up behind Parker Dam for about 45 miles and covers about 25,000 acres. Lake Havasu serves as a forebay from which the Metropolitan Water District of Southern California pumps water into the Colorado River Aqueduct. Lake Havasu also controls floods originating below Davis Dam.

Headgate Rock Dam, Palo Verde Diversion Dam, and Imperial Dam all serve as diversion structures with practically no storage. Imperial Dam, located some 150 miles downstream from Parker Dam, is the major diversion structure to irrigation projects in the Imperial Valley and Yuma areas. It diverts water on the right bank to the All American Canal which delivers water to the Yuma project in Arizona and California and Imperial and Coachella Valleys in California. It diverts on the left bank to the Gila Gravity Main Canal.

The Senator Wash Dam also affords regulation in the vicinity of Imperial Dam and assists in the delivery of water to Mexico.

PART III. HISTORY OF WATER RESOURCE DEVELOPMENT

A. Irrigation Development

Irrigation development in the Upper Basin took place gradually from the beginning of settlement about 1 60 but was hastened by the purchase of land from the Indians in 1873. About 800,000 acres were irrigated by 1905. Between 1905 and 1920 the development of irrigated land continued at a rapid pace, and by 1920 nearly 1,400,000 acres were irrigated. The development then leveled off and increase since that time has been slow. In 1965, 1,600,000 acres were under irrigation in the Upper Basin.

The slow growth in irrigated acreage in the Upper Basin in the last 45 years is ascribed to both physical and economic limitations on the availability of water. By 1920 most of the lower cost and more easily constructed developments were in operation, and, although some new developments have taken place since that time, they have been partially offset by other acreages going out of production.

Irrigation development began in the Lower Basin about the same time as in the Upper Basin. Development was slow because of difficult diversions from the Colorado River with its widely fluctuating flows. Development of the Gila area began in 1875 and the Palo Verde area in 1879. The development rate increased in the period 1900-10 with construction of the Yuma Project, the Palo Verde Canal and intake, and other irrigation projects along the river. Construction of Boulder Canyon Project in the 1930's and other downstream projects since that time has continued to expand the irrigated areas until about 25,500 acres in Utah, 12,000 acres in Nevada, and 789,500 acres below Hoover Dam are irrigated under organized irrigation systems. An additional unknown acreage is irrigated by private pumping from wells in the river aquifers in the Lower Colorado River Basin.

B. Streamflow Depletions

Development and utilization of the basin's water resources results in depletions of streamflows. Consumptive use of water by irrigated crops and exports to other basins produce the greatest flow depletions. Reservoir evaporation and consumptive use of water for municipal and industrial purposes also produce significant depletions.

For the 1941-68 period of record consumptive use of water by irrigated crops in the Upper Basin was estimated to average 1,727,000 acre-feet annually. This is low in comparison to the irrigated acreage, but some lands do not receive a full supply.

Water exported from the Upper Basin during the same period averaged about 357,000 acre-feet per year. Since completion of the Colorado-Big Thompson Project with initial diversions made in year 1947, the Duchesne Tunnel completed in 1953, and the Roberts Tunnel completed in 1963, the transmountain diversions have increased to around 500,000 acre-feet.

Consumptive use of water for municipal and industrial purposes in the Upper Basin produced a minor depletion of about 30,000 acre-feet annually.

Reservoir evaporation varies from year to year but the variations have little effect on average streamflow depletions. For the period of record considered, average reservoir evaporation in the Upper Basin was minor as the large reservoirs of the Colorado River Storage Project did not begin filling until late in the period. Under normal operating conditions, evaporation from the Colorado River Storage Project reservoirs is expected to average about 600,000 acre-feet annually.

For the 1941-68 period of record, streamflow depletions in the Upper Basin totaled about 2 million acre-feet.

In the Lower Basin above Imperial Dam water is exported to the Southern California coastal areas and to Imperial and Coachella Valleys and delivered to irrigated areas along the river in Arizona and California, principally to the Colorado River Indian Reservation, Palo Verde Irrigation District, Gila Project, and Yuma Project. Water is also delivered to Mexico at the International Boundary as well as consumed by phreatophytes or evaporated.

C. Legal Aspects

1. Colorado River Compact

Water of the Colorado River was divided between the Upper and Lower Colorado River Basins by the Colorado River Compact which was signed in 1922 by a commissioner of each of the seven States of the river basin and by a representative of the United States. All States but Arizona ratified the compact prior to its effective date in 1929. The dividing point on the river between the Upper and Lower Basins is at Lee Ferry which is defined as a point 1 mile below the mouth of the Paria River. The compact apportions from the Colorado River system to each of the Upper and Lower Basins in perpetuity for exclusive beneficial consumptive use a total of 7,500,000 acre-feet annually. In addition to the apportionment of 7,500,000 acre-feet, the Lower Basin is given the right to increase its beneficial consumptive use of water from the Colorado River system by 1 million acre-feet annually. The compact further provides that the States of the upper division will not cause the flow of the river at Lee Ferry to be depleted below an aggregate of 75 million acre-feet for any period of 10 consecutive years.

One provision in the compact permits exportation of the water out of the basin as long as it is used beneficially in the seven Basin States, and another provision recognizes the obligations of the United States to the Indian Tribes. The compact prescribes the manner in which the waters of the Colorado River system may be made available to Mexico under any water rights recognized by the United States.

The compact, in effect, cleared the way for legislation authorizing the construction of major projects such as Boulder Canyon Project, and it also cleared the way for compacts or agreements within the Upper and Lower Basins to further divide the water among the States.

2. Mexican Treaty

The treaty with Mexico, signed in 1944, provides basically for a guarateeed annual delivery by the United States to Mexico of 1,500,000 acre-feet of Colorado River water.

3. Upper Colorado River Basin Compact

With the water allocated to the Upper Basin by the Colorado River Compact and with the Mexican Treaty signed, the Upper Basin States began negotiations which resulted in the signing of the Upper Colorado River Basin Compact in 1948. Under the terms of the compact, Arizona is permitted to use 50,000 acre-feet of water annually from the Upper Colorado River system, and the remaining water is apportioned to the other Upper Basin States in the following percentages.

State of Colorado	51.75 percent
State of New Mexico	11.25 percent
State of Utah	23.00 percent
State of Wyoming	14.00 percent

Congress had previously been unwilling to approve projects without assurance that a water supply would be available, so this division of water among the States permitted development in the Upper Basin to proceed and resulted primarily in the authorization of most of the Federal projects above Lee Ferry that are mentioned in this report.

Neither of the compacts specifically mentions water quality, but it has been recognized as a factor to be considered in developing projects, and water quality studies have been required by recent legislation authorizing the construction of projects in the Upper Basin.

4. Arizona vs. California Suit in the Supreme Court

The States of the Lower Basin have never agreed to a compact for the division of use of the waters of the Lower Colorado River Basin. The

State of Arizona filed suit in the Supreme Court of the United States in October 1952 against the State of California and others for the determination of the rights to use the waters of the Lower Colorado River system. The Supreme Court gave its decision on June 3, 1963, and issued a decree on March 9, 1964, providing for the apportionment of the use of the waters of the main stream of the Colorado River below Lee Ferry among the States of Arizona, California, and Nevada. The States of Arizona and New Mexico were granted the exclusive use of the waters of the Gila River system in the United States. The decree did not affect the rights or priorities to the use of water in any of the other Lower Basin tributaries of the Colorado River.

The decree permitted the States of the Lower Basin to proceed with developments to use their apportionments of Colorado River water. Major new developments include the Southern Nevada Water Project in Nevada, the Dixie Project in Utah, and the Central Arizona Project in Arizona. Development of the Indian lands is expected to use all of the water allocated to them by the decree. These lands include the Colorado River Indian Reservation, Arizona-California; the Fort Mohave Indian Reservation, Arizona-California-Nevada; and the Chemehuevi Indian Reservation, California.

5. Colorado River Basin Project Act (Public Law 90-537, 90th Congress, September 30, 1968)

The major items provided in the law include the following:

Construction of the Central Arizona Project consisting of a system of main conduits and canals including a main canal and pumping plants (Granite Reef aqueduct and pumping plants) for diverting and carrying water from Lake Havasu to Orme Dam or suitable alternative.

Construction of five multiple-purpose projects in Colorado; the Animas-La Plata, Dolores, Dallas Creek, West Divide, and San Miguel; and one in Utah, the Uintah Unit of the Central Utah Project, upon completion and approval of a feasibility report to Congress.

Establishment of a Lower Colorado River Development Fund.

Development of criteria for the coordinated long-range operation of the Federal reservoirs, equalizing the storage in Lake Mead and Lake Powell.

Directed that the Secretary of the Interior shall conduct full and complete reconnaissance investigations for the purpose of developing a general plan to meet the future water needs of the Western United States, except that for a period of 10 years from the date of the act, studies shall not be undertaken of any plan for the importation of water into the Colorado River Basin from any other natural river drainage basin lying outside the States of Arizona, California, Colorado, New Mexico, and those portions of Nevada, Utah, and Wyoming which are in the natural drainage basin of the Colorado River.

Directed the Secretary to make reports of annual consumptive use and losses of water from the Colorado River system.

D. Economic Conditions

The prosperity of agriculture in the Upper Colorado River drainage basin generally parallels the prosperity of the livestock industry. With vast areas of fine rangeland available for summer grazing, livestock production is limited by the production of hay for winter feed.

Intensified development of mineral resources in recent years has created new employment opportunities, including off-the-farm work for many farmers. The most extensive and commercially important mineral resources of the Upper Basin are coal, oil, and natural gas. The Upper Basin is also the leading domestic source of vanadium, uranium, radium ore, and molybdenum. Copper, zinc, lead, silver, and gold are also commercially important. In recent years mining of trona has become extensive in the State of Wyoming. The increase in population resulting from new job opportunities has created new markets for locally produced and imported products, has taxed municipal facilities and water supplies in several areas, and has increased demands for electricity. Raw materials are stimulating industrial activities in areas adjoining the upper drainage basin, particularly areas near Denver, Pueblo, Provo, and Salt Lake City. These adjoining areas all import water from the Colorado River Basin and without the imported water their economic growth would be limited.

Tourism as an industry has increased significantly in recent years because of the many natural attractions. Manufacturing as a basic industry is of relatively minor importance in the Upper Basin.

Irrigated areas in the Lower Colorado River Basin and in adjoining basins using Colorado River main stream water are highly productive and the agricultural operations very intensified. Gross crop values per acre probably are greater than any other area of comparable size in the world with a 1968 average gross crop income of $415 per acre.

The Pacific Southwest is one of the most rapidly developing areas in the Nation, both industrially and populationwise. Colorado River water for municipal and industrial purposes is supplied to approximately 130 incorporated towns and other communities in this area with a population of about 10 million people. This water supply, which totaled about 1,200,000 acre-feet in 1968, ranges from a minor supplemental supply for some entities to a complete supply for others.

PART IV. BASIC STUDIES

A. Study Objectives

The Secretary of the Interior is required by various legislative acts to report on the quality of water in the Colorado River Basin, to evaluate the suitability of the water for beneficial uses, to estimate the effects of future development on water quality, and to investigate means of improving water quality. A number of basic studies have been undertaken by the Bureau of Reclamation, the Geological Survey, and the Federal Water Quality Administration in compliance with these legislative requirements.

These studies include the collection of data for evaluating quality of water investigations, studying the effects existing water resource developments have had on water quality, detecting and defining water quality trends and predicting the effects of future development on water quality, defining the suitability of Colorado River water for beneficial use, and evaluating water quality control measures. These studies are discussed in the following Parts IV to IX of this report.

B. Effects of Impoundments

1. Flaming Gorge Reservoir

Quality of water in the reservoir.--In October 1966 and September 1968 water quality samples were collected at the surface, bottom, and seven intermediate points from each of six sites in the reservoir. Some additional data are also available from three sites for September 1967. The approximate dissolved-solids distribution in the reservoir during sampling times is shown in Figures 2 and 3 . Available data are insufficient to define the annual limnological cycle of Flaming Gorge Reservoir. Figures 2 and 3 represent chemical-quality conditions in the reservoir in the fall of 1966, 1967, and 1968. The less concentrated spring and summer runoff can be seen at the lower end of the reservoir. These exiguous data for the period 1966-68 indicate that the water probably takes an average of about 3 months to move the length of the reservoir.

The measured load of dissolved solids in the reservoir on October 1, 1966, was about 1,850,000 tons. This figure was computed using the chemical-quality data from the six sampling verticals and area capacity curves. In order to determine initial leaching and storage, a theoretical load as of October 1, 1966, was also computed, using available inflow and outflow data. The theoretical load was 1,050,000 tons, and this represents the net amount of dissolved solids contributed to the reservoir

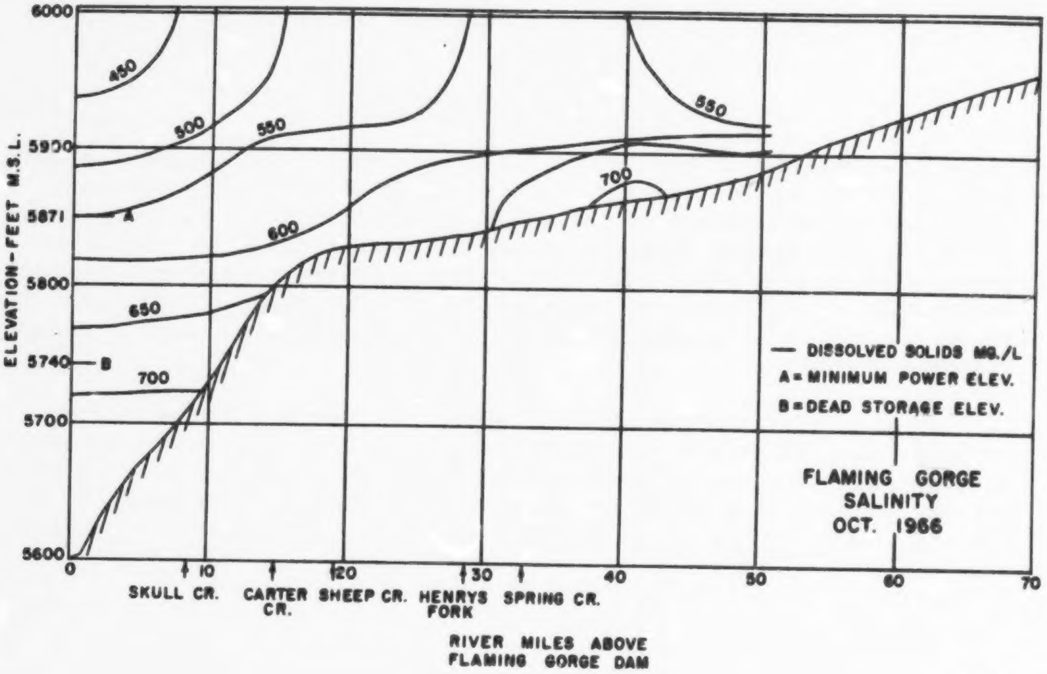

6000
5900
5871
A
5800
5740
B
5700
5600
ELEVATION-FEET M.S.L.
450
500
550
550
600
650
700
700
— DISSOLVED SOLIDS MG./L
A = MINIMUM POWER ELEV.
B = DEAD STORAGE ELEV.
FLAMING GORGE
SALINITY
OCT. 1966
0
10
20
30
40
50
60
70
SKULL CR.
CARTER CR.
SHEEP CR.
HENRYS FORK
SPRING CR.
RIVER MILES ABOVE
FLAMING GORGE DAM

Fig. 2

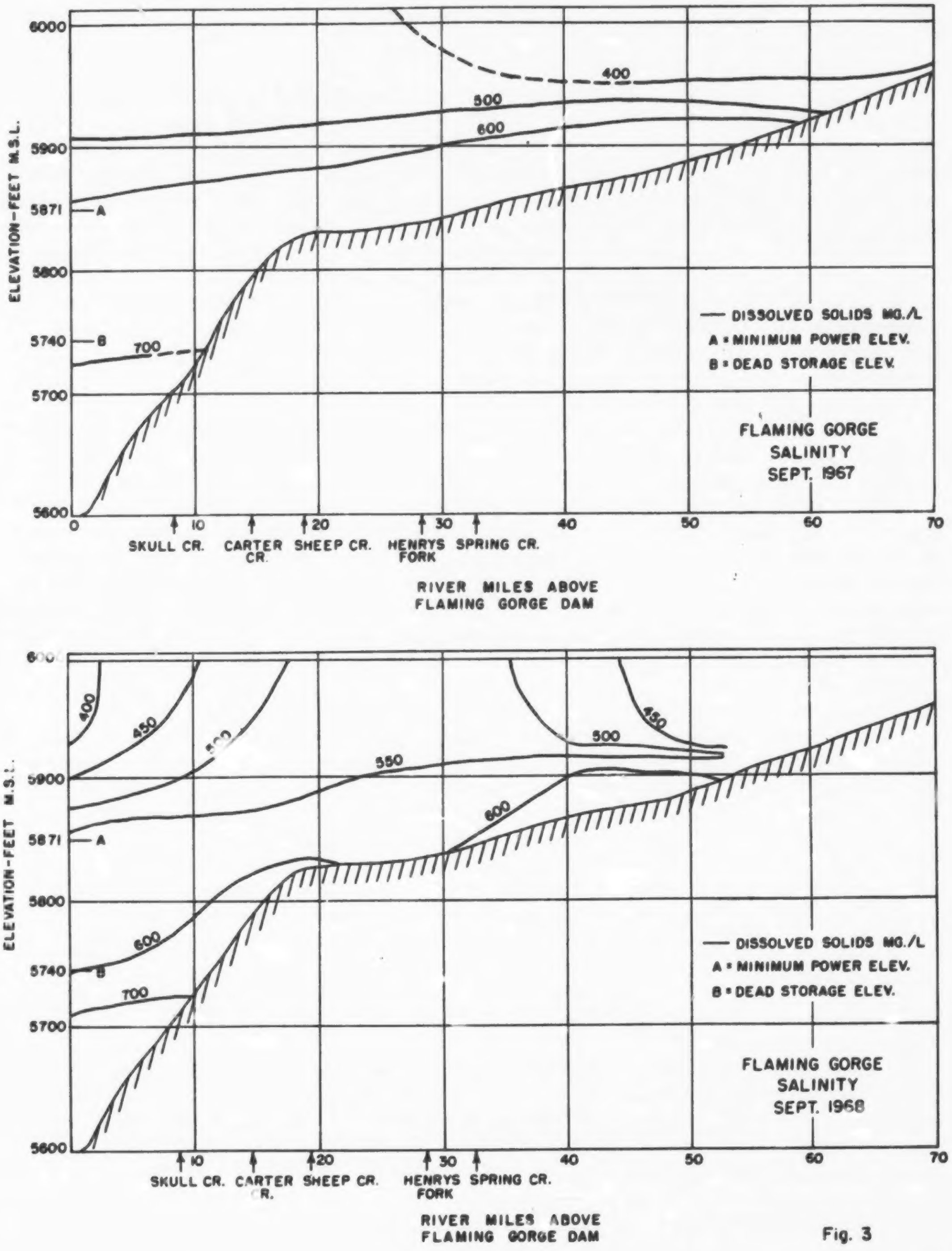
6000
5900
5871 — A
5800
5740 — B
5700
5600
ELEVATION-FEET M.S.L.
400
500
600
700
— DISSOLVED SOLIDS MG./L
A = MINIMUM POWER ELEV.
B = DEAD STORAGE ELEV.
FLAMING GORGE
SALINITY
SEPT. 1967
0
10
20
30
40
50
60
70
SKULL CR.
CARTER CR.
SHEEP CR.
HENRYS FORK
SPRING CR.
RIVER MILES ABOVE
FLAMING GORGE DAM
6000
5900
5871 — A
5800
5740 — B
5700
5600
ELEVATION-FEET M.S.L.
400
450
500
550
600
500
450
600
700
— DISSOLVED SOLIDS MG./L
A = MINIMUM POWER ELEV.
B = DEAD STORAGE ELEV.
FLAMING GORGE
SALINITY
SEPT. 1968
10
20
30
40
50
60
70
SKULL CR.
CARTER CR.
SHEEP CR.
HENRYS FORK
SPRING CR.
RIVER MILES ABOVE
FLAMING GORGE DAM

Fig. 3

from runoff. The data used to arrive at the above figures are not seasonally continuous and they cover only a short period of time (1957-66). The chemical quality of the major inflowing tributaries (Green River at Green River, Wyo., Blacks Fork at Little America, Wyo., and Henrys Fork at Linwood, Utah) has been measured since 1952, but the flow at Greendale has been observed only since 1957 after construction began; thus the relationship used to estimate unmeasured inflow is not precise. For these reasons the figures should be considered as estimates only. The difference of 800,000 tons between the measured load and the theoretical load represents the estimated amount of dissolved solids added to the river system by leaching during the first 4 years after closure of the reservoir.

The load of dissolved solids in the reservoir measured in September 1968, 2 years later, was about 1,500,000 tons. Starting with 1,850,000 tons of total dissolved solids in storage on October 1, 1966, the theoretical load, or the total amount of dissolved solids, which should have been in the reservoir as the result of runoff, was about 1,100,000 tons. Thus, in the 2-year period ending in September 1968, the amount of dissolved solids leached from the inundated area was about 400,000 tons, or one-half the amount leached in the previous 4-year period. On the basis of these calculations, it would appear that the rate of leaching has not decreased significantly over the first 6 years since the reservoir was closed.

The major observable changes in chemical composition occurring in the reservoir are an increase in the percentage of sulfate and a decrease in the percentage of bicarbonate compared with the chemical composition of the inflow. The inflowing water during the 1963-66 period contained about equal percentages of sulfate and bicarbonate ions (47 percent of the total anions). The water in the reservoir on October 1, 1966, contained about 34 percent bicarbonate and 57 percent sulfate. The percentage of the other ions has remained about the same. The change in the percentage of bicarbonate and sulfate ions relative to the other ions in solution may be the result of leaching of gypsum ($CaSO_4.2H_2O$) and other sulfate soluble evaporites from the inundated areas and of precipitation of calcium carbonate ($CaCO_3$).

The chemical composition of water in the reservoir itself, although it is different from that of the inflow, is very uniform. The dissolved-solids concentration shows a definite increase with depth, but the percentage of individual ions is essentially the same throughout the major portion of the reservoir.

Quality of inflow waters.--The major inflow to the reservoir is from Green River which contributes 70-95 percent of the water, but only 55-65 percent of the inflow load of dissolved solids. Because of their higher concentrations of dissolved solids, Blacks Fork and Henrys Fork contribute a higher percentage of the dissolved-solids load than they do of water.

The minor tributaries contribute less than 10 percent of the total inflow to the reservoir and account for less than 15 percent of the total incoming load. The streams draining into the upper part of the reservoir above Henrys Fork are mostly intermittent. The total amount of water they contribute is small, but they are high in dissolved-solids content. Carter Creek, Cart Creek, and Sheep Creek, which drain into the lower section of the reservoir from mountainous areas, contribute larger amounts of water but are more dilute.

Effects of closure on the Green River at Greendale.--The closure of Flaming Gorge Dam has been too recent (November 1962) to allow a statement as to its ultimate effect on the chemical quality of the water downstream. Data for the first 7 years since closure indicate an initial increase in the average dissolved-solids concentration of the water at Greendale. The highest weighted-average dissolved-solids concentration occurred in 1963 when a minimum of water was being released as the reservoir filled. During the next 6 years (1964-68) the annual weighted-average dissolved-solids concentrations were less than in 1963 but greater than during the 6 years preceding closure. Information is not available on the chemical quality of the water below the reservoir prior to 1957 when construction of the dam began. Construction operations from 1957 to 1962 probably had some effect, and the concentration and load of dissolved solids in the Green River prior to the beginning of construction may have been slightly different from that for the 1957-62 period.

The annual weighted-average concentrations of all major constituents have increased in the water at Greendale since closure of the reservoir with sulfate having the most pronounced increase. The percentage composition (in milliequivalents per liter) of calcium, magnesium, sodium, and chloride has remained about the same after closure as before closure. However, the percentage of bicarbonate has decreased, while that of sulfate has increased. These changes in composition are due to chemical changes in the reservoir as previously discussed.

2. Lake Powell

Quality of water in reservoirs.- Water quality studies were started by the Bureau of Reclamation at Lake Powell in January 1965 as the lake was approaching inactive storage level. The program is to collect and analyze water samples four times a year at seven different locations. January, May, July, and October are designated as the months of collection and in addition samples are taken once a month at the mouth of Wahweap Creek. The samples are taken at 50-foot intervals to the bottom of the lake. Results of the sampling for 1968 are shown on the accompanying isohaline graphs. (Figures 4 and 5.)

The graphs show that for any point in the reservoir the salt concentration generally increases with depth. The exceptions are probably caused by colder-less saline water flowing under the warmer-more saline

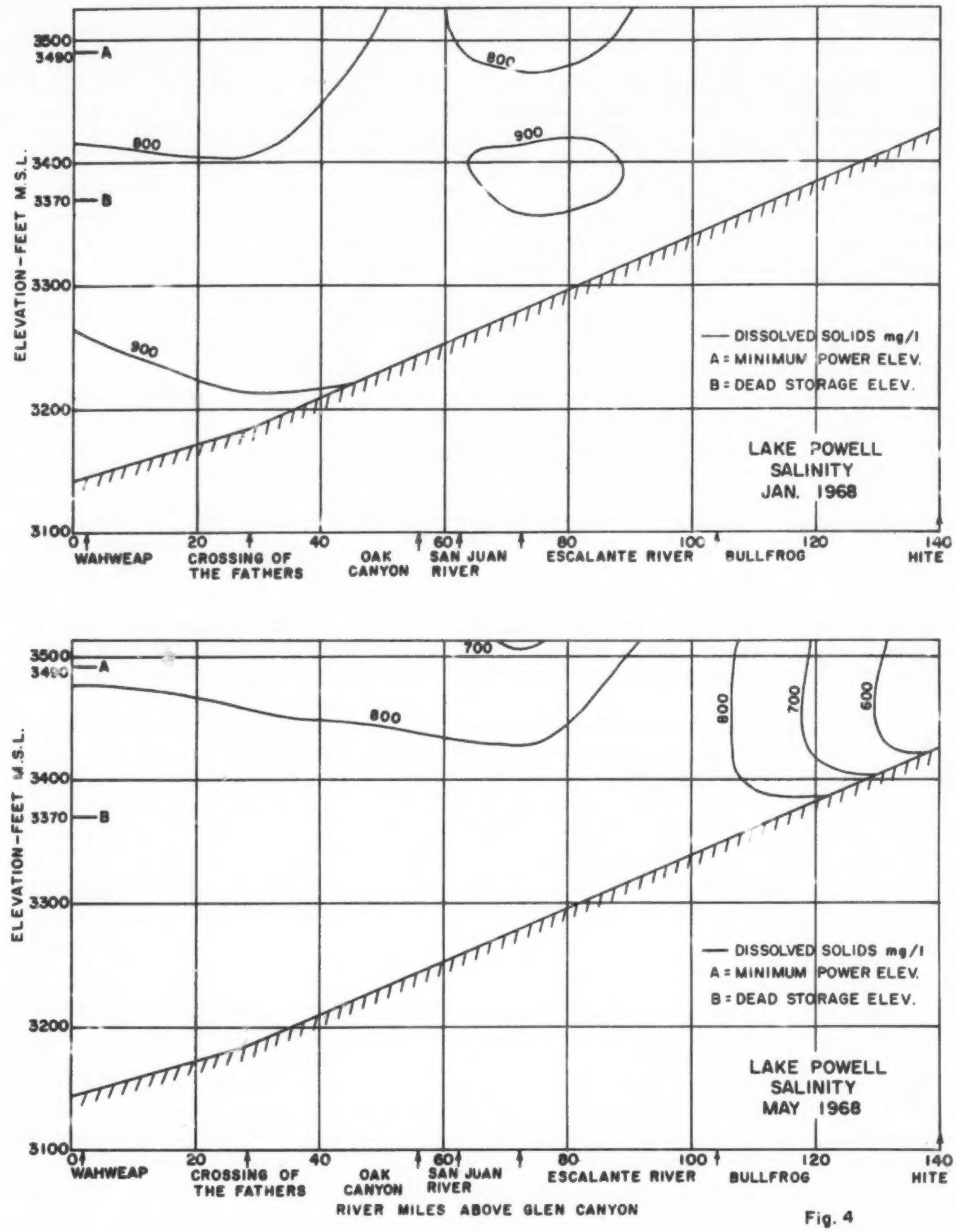

LAKE POWELL
SALINITY
JAN. 1968
— DISSOLVED SOLIDS mg/l
A = MINIMUM POWER ELEV.
B = DEAD STORAGE ELEV.
ELEVATION-FEET M.S.L.
3500
3490 A
3400
3370 B
3300
3200
3100
800
800
900
900
0
20
40
60
80
100
120
140
WAHWEAP
CROSSING OF THE FATHERS
OAK CANYON
SAN JUAN RIVER
ESCALANTE RIVER
BULLFROG
HITE
LAKE POWELL
SALINITY
MAY 1968
— DISSOLVED SOLIDS mg/l
A = MINIMUM POWER ELEV.
B = DEAD STORAGE ELEV.
700
800
800
700
600
RIVER MILES ABOVE GLEN CANYON

Fig. 4

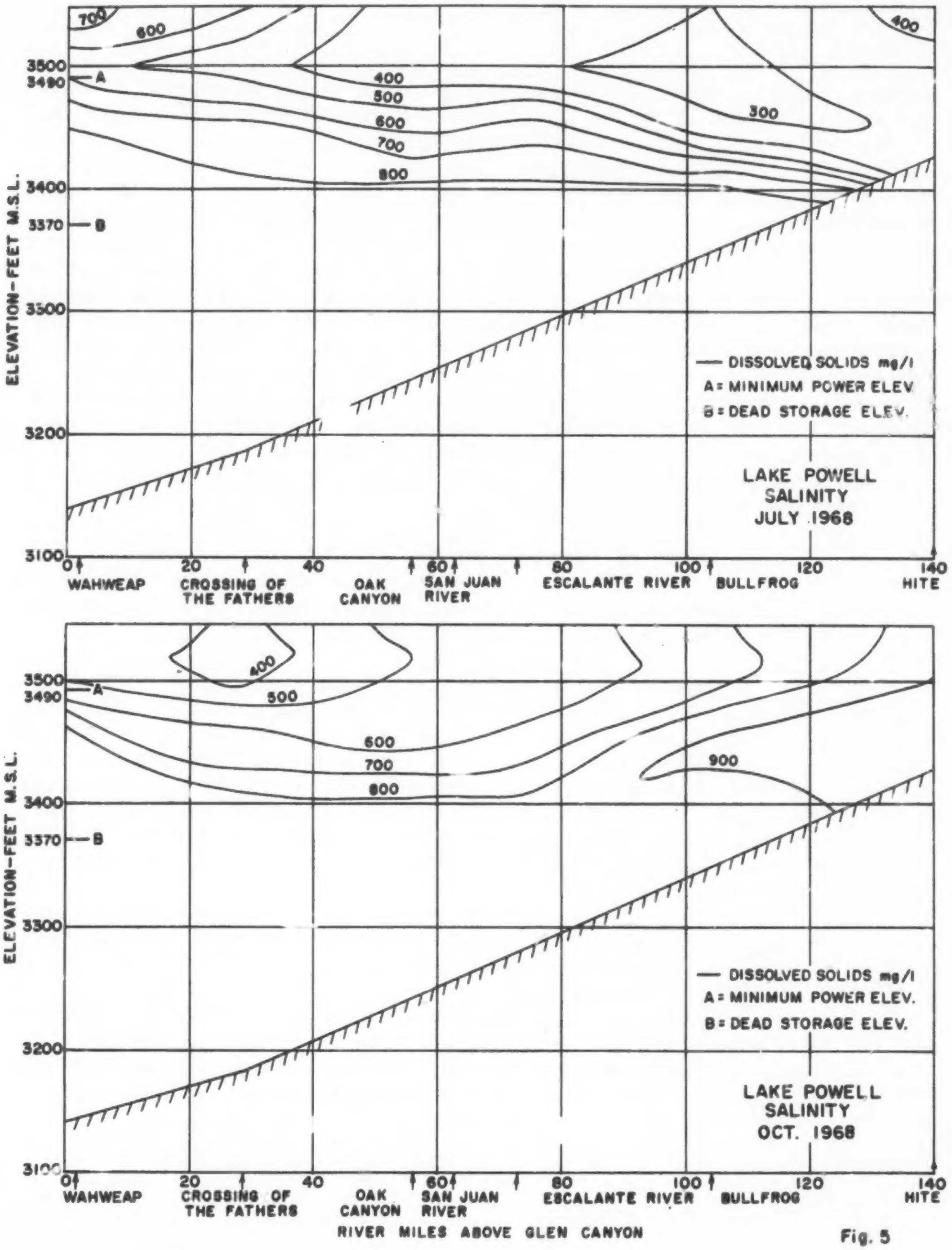

700
600
400
3500
3490
A
400
500
600
700
800
300
3400
3370
B
3500
3200
3100
ELEVATION-FEET M.S.L.
— DISSOLVED SOLIDS mg/l
A = MINIMUM POWER ELEV.
B = DEAD STORAGE ELEV.
LAKE POWELL
SALINITY
JULY 1968
0
20
40
60
80
100
120
140
WAHWEAP
CROSSING OF THE FATHERS
OAK CANYON
SAN JUAN RIVER
ESCALANTE RIVER
BULLFROG
HITE
400
500
600
700
800
900
3500
3490
A
3400
3370
B
3300
3200
3100
ELEVATION-FEET M.S.L.
— DISSOLVED SOLIDS mg/l
A = MINIMUM POWER ELEV.
B = DEAD STORAGE ELEV.
LAKE POWELL
SALINITY
OCT. 1968
RIVER MILES ABOVE GLEN CANYON

Fig. 5

water without mixing. The January graph shows the concentration near the surface of the reservoir generally increasing toward the upper end of the reservoir, probably resulting from the more saline flows of summer and fall from the Colorado and Green Rivers. As the winter and spring flows with less concentration enter the reservoir, the May chart shows the higher concentrated water above the Escalante River becomes diluted. The July chart shows the less saline flows of the high runoff from the Colorado and Green Rivers have moved down the reservoir, flowing mainly over the more saline water already in storage. Also the July chart shows the beginning of the more saline summer flows entering the reservoir. The October chart shows the less saline flows have moved farther down the reservoir, diluting the more saline water slightly. It also shows the more saline summer and fall flows from the Colorado and Green Rivers moving into the reservoir and flowing under the less saline waters. This is one interpretation of the data from the sampling program. The isohaline graphs could be drawn slightly different for other interpretations of the data.

The concentration of the flow in the river below the dam when compared with the concentration at Wahweap for the minimum power elevations indicates that some of the water passed through the powerplant penstock comes from the more concentrated water from lower elevations.

Effects of closure on the Colorado River at Lees Ferry.--The discharge-weighted, average concentration of dissolved solids in the water from the Colorado River at Lees Ferry for the 1941-62 period was a function of the river discharge. This relation is shown in Figure 6 . However, since 1962 this relation has been affected by storage of water in Lake Powell. The concentrations of dissolved solids at Lees Ferry were higher than would have been expected without storage during the first 3 years of regulation and were lower than expected during the ensuing 2 years (1966-67).

By adjusting the discharge at Lees Ferry for storage in Lake Powell beginning with 1963, the dissolved-solids concentration that would have been expected without storage was obtained from the established dissolved-solids discharge relation. The tabulation on page 26 shows the measured and adjusted discharges and measured and expected weighted-average dissolved-solids concentrations for the Colorado River at Lees Ferry for the period 1963-68. (The data for 1968 are preliminary.)

RELATION BETWEEN ANNUAL AVERAGE STREAMFLOW
AND DISSOLVED SOLIDS CONCENTRATIONS 1941-68
COLORADO RIVER AT LEES FERRY, ARIZONA

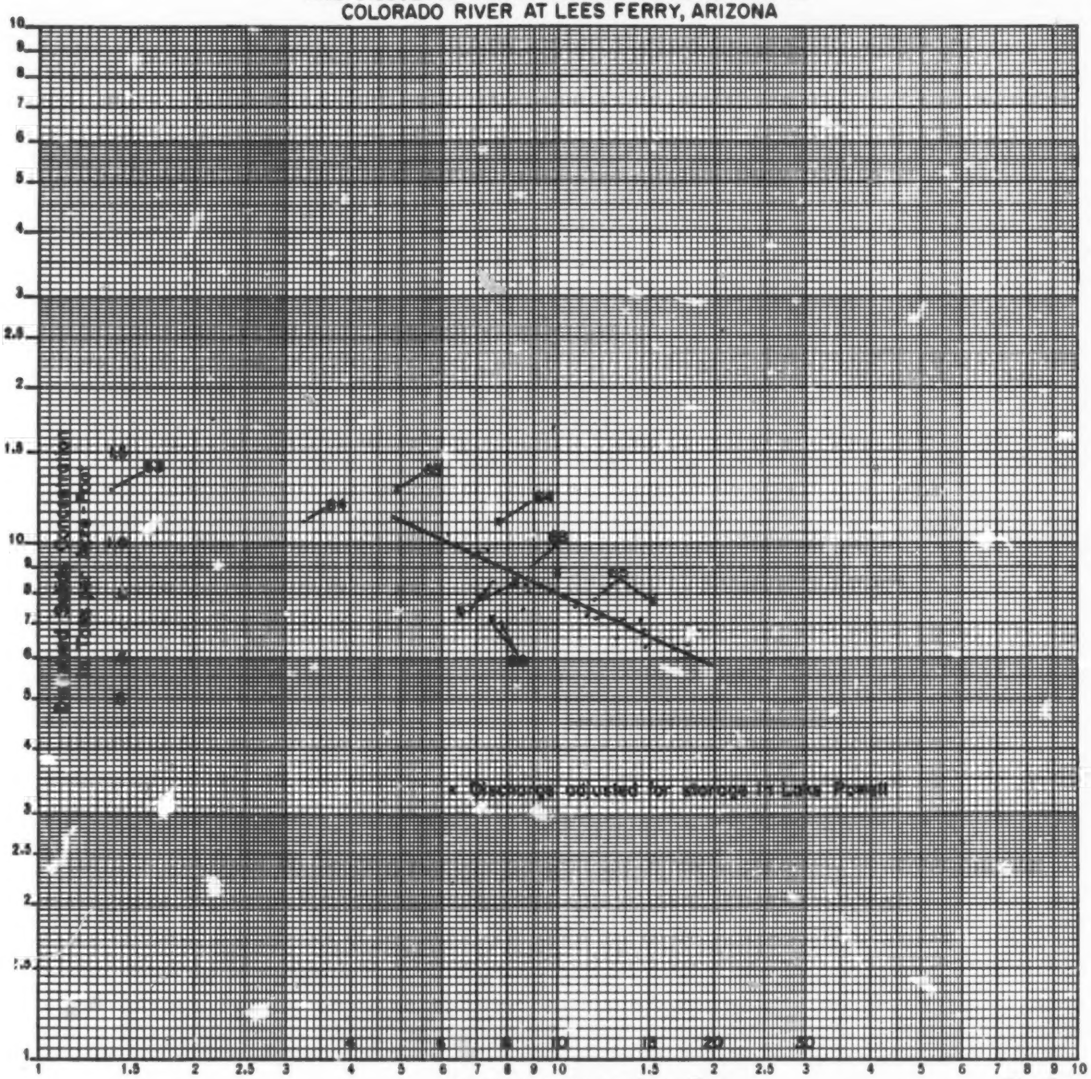


Fig. 6

Colorado River at Lees Ferry

Calendar year	Expected (mg./l.)	Expected tons per acre-foot	Historical (mg./l.)	Historical tons per acre-foot	Discharge (million acre-feet) Adjusted	Discharge (million acre-feet) Historical
1963	825	1.12	935	1.27	4.94	1.38
1964	675	.92	810	1.10	7.68	3.24
1965	485	.66	575	.78	15.15	11.59
1966	675	.92	515	.70	7.60	7.74
1967	650	.88	625	.85	8.45	7.56
1968	560	.76	650	.88	10.14	8.78

The data from the above tabulation plotted in Figure 6 show that during the filling of the reservoir (1963-65) the measured concentrations of dissolved solids in the water released from the reservoir were greater than would have existed without the storage. However, during 2 years of withdrawing water from storage, 1966-67, the measured concentrations were less than the expected.

The concentration in years subsequent to the start of regulation is influenced by the concentration of the water already in storage and the degree of stratification in the reservoir, as well as runoff conditions in the given year. Thus it is believed the concentrations at Lees Ferry in 1963, 1964, and 1965 were somewhat higher than would have been expected without storage because of initial storage of water of higher than average concentrations in 1963, relatively low runoff in 1963 and 1964, and because the water released contained a higher concentration of dissolved solids than the average concentration of dissolved solids of the water in storage owing to salinity stratification in the reservoir.

The rather large reduction in outflow concentration occurring in 1966 resulted from the diluting effect of the unusually high inflow of dilute water during the spring runoff period of 1965.

The increase in concentration of outflow water in 1967 resulted because total inflow and the ratio of spring inflow to total flow in both 1966 and 1967 was lower than in 1965.

The effects of evaporation and chemical precipitation due to Lake Powell cannot yet be clearly evaluated.

Experience is too short at this time to define a concentration-discharge relation at Lees Ferry subsequent to the closing of Glen Canyon Dam. In fact, one should not expect a close correlation between concentration and discharge at Lees Ferry. There will always be a lag in the response of concentration of outflow water at Glen Canyon Dam to inflow conditions due to storage and stratification in the reservoir. This is borne out by experience below Hoover Dam.

3. Lake Mead

The Bureau of Reclamation conducted an extensive quality sampling program of Lake Mead from 1964 through 1968. As many as 28 stations were sampled in the spring and fall. Tests were made for dissolved oxygen, carbon dioxide, pH, alkalinity, temperature, conductivity, and turbidity at selected depths at each station. Water samples were obtained from selected depths for laboratory analysis for calcium, magnesium, sodium, potassium, carbonate, bicarbonate, sulphate, chloride, nitrate, phosphate, electrical conductivity, total dissolved solids, and pH. The results of these investigations were correlated with the sampling station at Hoover Dam where monthly water analyses of many of these factors have been made for over 20 years. The data collected from the sampling program during the period April 1964 through November 1966 were published in Report No. CHE-70, Water Quality Study of Lake Mead, November 1967, Bureau of Reclamation, Denver, Colorado.

This report documents the effect of the reduced inflow on water quality and the improvement of quality with increased inflow to the lake following the initial filling of Lake Powell.

The report discusses the limnological characteristics of Lake Mead. The annual temperature cycle of Lake Mead is classified as warm monomictic in that the temperature is never below 39.2° F., undergoes circulation during the winter, and is directly stratified in the summer.

There is an increase in mineral content from the upper to the lower end of Lake Mead with the greatest increases being in sulphates and chlorides of calcium and sodium. The only decrease noted was in the bicarbonate values.

It is expected that the type of sampling made during this survey will be repeated at appropriate intervals in the future.

C. Lower Colorado River Salinity Investigations

Water quality data from 58 locations in the Lower Colorado River Basin are being used in a special study instituted by the Bureau of Reclamation in 1970 to more clearly define the sources of salinity contribution between Parker Dam and Imperial Dam. To acquire the necessary data for the study, the sampling frequency was increased to obtain daily specific conductance, weekly TDS analyses by evaporation, and monthly chemical analyses at 10 stations as follows: Colorado River below Parker Dam; Colorado River Indian Reservation Main Canal near Parker; Poston Wasteway near Poston; Colorado River Indian Reservation Levee Drain near Parker; Palo Verde Canal near Blythe; Colorado River Indian Reservation

Lower Main Drain near Parker; Colorado River at Taylor Ferry near Cibola; Palo Verde Irrigation District Outfall Drain near Palo Verde; Colorado River below Cibola Valley; and Colorado River at Imperial Dam.

D. Natural Sources of Salinity

Inspection of the flow and quality records reveals that along certain reaches of the Colorado River there are large increases in the dissolved-solids load that cannot be attributed to irrigation. This increase is mainly due to natural diffused sources and the saline springs and wells in the Colorado River Basin. Although wells are man-made and not a natural source, abandoned saline flowing wells are also presented in this section.

1. Diffused Sources

Natural diffused sources are those sources of salt contribution which occur gradually over long reaches of the river system.

Salt pickup occurs over large areas of surface and underlying soils, from stream channels and banks, and is difficult to identify, measure, or control. This source contributes the largest overall share of the salts to the Colorado River. Natural point sources are mainly saline springs where the contribution of salt and water is easily identified, issuing from single or concentrated sources.

Past records indicate an increase in salt load in the Lake Powell area above Lees Ferry and below the Green River, Cisco, and Bluff stations. Iorns and others (1965, p. 20) presented estimates of dissolved-solids loads in this river reach based on the period 1914-57 adjusted to 1957 conditions of development. Unaccounted inflow of dissolved solids in this reach amounted to about 5 percent of the load at Lees Ferry.

During 3 consecutive years (1949-51) when there was very little increase in water discharge between Lees Ferry and Grand Canyon, the dissolved-solids load increased about 1.3 million tons each year. During 1951 the discharge increased by about 1 million acre-feet, but the load increased by only 2 million tons. In 1952 the discharge increased by 0.2 million acre-feet and the load by 2.2 million tons. With the exception of these 2 years the annual increase in dissolved-solids load during the 28-year period has ranged from 0.5 million tons to 1.8 million tons.

In 1962 runoff of 14.4 million acre-feet at Lees Ferry increased by 400,000 acre-feet at Grand Canyon and the dissolved-solids load increased by half a million tons. By contrast, during the filling of Lake Powell the following year, only 1,384,000 acre-feet was recorded at Lees Ferry and the increase in flow at Grand Canyon amounted to 246,000 acre-feet, but the dissolved-solids load still increased by more than a half million tons. Likewise, with a small flow in 1964 the dissolved-solids load increased by nearly 900,000 tons.

Large amounts of dissolved solids also are added to the Colorado River between Grand Canyon and Hoover Dam. This does not result entirely from the solution of material in the bed of Lake Mead, but definition of specific sources along this reach of the river is difficult.

Very little information was obtained prior to irrigation and therefore more studies are needed to identify the magnitude of specific natural sources of salinity in the Colorado River Basin.

2. Contribution of Salts to the River System by Springs and Tributaries

Tables A and B summarize information about the contribution of water and dissolved salts by springs and wells to the Upper Colorado River system. The largest contributors in the Upper Basin are the Dotsero and Glenwood Springs which supply the major part of the salts from point sources. Recent studies in the Lower Basin by the Geological Survey and the Bureau of Reclamation have provided information about the contribution of springs to the Colorado River between Glen Canyon Dam and Lake Mead and to the Virgin River which drains into Lake Mead. The results of these studies are presented in the following paragraphs.

Between Glen Canyon Dam and Lake Mead numerous springs and small spring-fed tributary streams, as well as several large streams, contribute water and dissolved solids to the Colorado River. The largest contributors of dissolved solids are the Paria and Little Colorado Rivers and Bright Angel, Tapeats, Kanab, and Havasu Creeks. Records summarized in this report for the hydrologic data stations on the Colorado River at Lees Ferry (just upstream from Paria River) and near Grand Canyon (just upstream from Bright Angel Creek) indicate that each year slightly more than a million tons of dissolved solids are added to the Colorado River in this reach alone. About half of this increase can be attributed to springs in the lower 13 miles of the channel of the Little Colorado River. The Virgin River salinity contribution is principally from the LaVerkin Springs about 40 miles northeast of Littlefield, Arizona.

Paria River.--Iorns and others (1965, Table 10, p. 346) estimated that the Paria River contributed about 34,000 tons of dissolved solids and 23,000 acre-feet of water annually to the Colorado River. Their estimates were based on the period 1914-57, adjusted to 1957 conditions of development. For the 1941-68 period the average annual contribution is about 30,000 tons of dissolved solids and 18,800 acre-feet of water. Sulfate, calcium, sodium, and magnesium are the major dissolved constituents making up this dissolved-solids discharge.

Table A
Mineral and Saline Springs
Upper Colorado River Basin[1]

				Total dissolved-solids concentration	
Spring and location	Flow (c.f.s.)	SO_4 (mg./l.)	Cl (mg./l.)	(mg./l.)	(tons ac.-ft
Castle Creek Spring near Moab, Utah	0.245	1,290	1,460	4,390	6.0
Onion Creek Spring near Moab, Utah	0.122	1,830	4,000	9,120	12.4
Cold Kendall Spr. nr. Kendall Ranger Sta., Wyo.	1.400	1,300	1	2,100	2.8
Ragen Spring on Muddy Cr. west of Ft. Bridger, Wyo.	0.089	1,620	3,380	9,210	12.6
Dotsero Sprs. 1.5 mi. west of Dotsero, Colo.	17.000	450	5,800	10,700	14.5
Glenwood Sprs. area, Glenwood Sprs., Colo.	18.000	1,150	10,000	18,900	25.5
Steamboat Sprs. at Steamboat Sprs., Colo.	1.400	615	1,400	6,140	8.4
Lithia Spring, Steamboat Sprs., Colo.	0.022	460	1,350	5,770	7.8
Piceance Creek Spring, Meeker, Colo.	0.022	401	632	4,650	6.5
Trimble Hot Spring, Durango, Colo.	0.066	1,010	240	3,250	4.4
Pagosa Hot Spring, Pagosa, Colo.	2.300	1,500	173	3,240	4.4
Pinkerton Hot Spring, Durango, Colo.	0.500	635	1,010	3,670	5.0
Yellow Creek Spring, Rangely, Colo.	0.089	58	750	9,370	12.7
Ridgway Hot Spring, Ridgway, Colo.	1.000	1,460	103	2,850	3.9
Paradise Hot Spring, Dunton, Colo.	0.111	134	2,800	5,490	7.5
Big Sulphur Spring, Meredith, Colo.	0.333	1,390	1	2,250	3.1
Arsenic Spring, Crystal Mining Camp	2.000	1,350	2	2,030	2.8
Coal Mine Drainage, Oak Creek, Colo.	0.666	1,960	4	3,430	4.7
Seepage to Big Sandy Cr., Farson, Wyo.	0.133	3,340	37	5,600	7.6
Total	45.498				

[1] List of springs limited to those with T.D.S. concentrations in excess of 2,000 mg./l.

A

Table A
Mineral and Saline Springs
Upper Colorado River Basin[1]

low f.s.)	SO_4 (mg./l.)	Cl (mg./l.)	Total dissolved-solids concentration (mg./l.)	(tons/ ac.-ft.)	Total dissolved-solids load tons/ day	tons/ year	Flow (ac.-ft./ year)
.245	1,290	1,460	4,390	6.0	2.9	1,060	177
.122	1,830	4,000	9,120	12.4	3.0	1,100	88
.400	1,300	1	2,100	2.8	7.9	2,880	1,014
.089	1,620	3,380	9,210	12.6	2.2	800	64
.000	450	5,800	10,700	14.5	500.0	182,600	12,308
.000	1,150	10,000	18,900	25.5	919.0	335,000	13,032
.400	615	1,400	6,140	8.4	23.4	8,500	1,014
.022	460	1,350	5,770	7.8	0.3	110	16
.022	401	632	4,650	6.5	0.2	72	16
.066	1,010	240	3,250	4.4	0.1	36	48
.300	1,500	173	3,240	4.4	20.0	7,300	1,665
.500	635	1,010	3,670	5.0	5.0	1,820	362
.089	58	750	9,370	12.7	2.3	840	64
.000	1,460	103	2,850	3.9	7.0	2,550	724
.111	134	2,800	5,490	7.5	1.7	620	80
.333	1,390	1	2,250	3.1	2.0	730	241
.000	1,350	2	2,030	2.8	11.0	4,000	1,448
.666	1,960	4	3,430	4.7	6.2	2,260	482
.133	3,340	37	5,600	7.6	2.0	730	96
.498					1,516.2	553,008	32,939

T.D.S. concentrations in excess of 2,000 mg./l.

B

Table B
Mineral and saline wells
Upper Colorado River Basin

Spring and location	Flow (c.f.s.)	SO_4 (mg./l.)	Cl (mg./l.)	Total dissolved-solids concentration		Total dissolved-solids load		Flow (acre-feet/ year)
				(mg./l.)	(tons/AF)	(tons/ day)	(tons/ year)	
South Drain, Ashley Creek Oil Field, Vernal, Utah	2.200	1,540	96	2,670	3.6	15.9	5,800	1,593
Crystal Geyser, Green River, Utah	.282	2,430	4,560	13,100	17.8	10.0	3,640	204
Oil Test Hole, Meeker, Colorado[1]	3.100	3,010	8,720	18,900	26.0	160.0	58,400	2,244
Flowing Well near Aneth, Utah	.133	1,980	763	4,560	6.2	1.6	580	96
Flowing Well 13.1 miles above mouth of Piceance Creek[1]	.355	11	554	17,900	24.4	17.2	6,280	257
Drainage, Iles Dome Oil Field near Loyd, Colorado	2.900	39	137	2,180	2.9	17.0	6,200	2,100
Total	8.970							6,494

[1] Plugged in summer of 1968.

Little Colorado River.--The water discharge of the Little Colorado River near Cameron, Arizona, which is above Blue Spring, has ranged during 1948-68 period from 19,260 acre-feet in 1956 to 347,600 acre-feet in 1952. The average for the 21-year period is 148,000 acre-feet. An estimated annual dissolved-solids discharge of 130,000 tons appears reasonable for the Little Colorado River Basin upstream from Blue Spring. This estimate is based on chemical-quality records collected at Cameron which is upstream from the gaging station and from Moenkopi Wash.

Blue Spring is in the bed of the Little Colorado River about 13 miles upstream from its mouth at approximately 36°07' N. latitude and 111°42' W. longitude. Other springs discharge into the channel of the Little Colorado River throughout a 10-mile reach downstream from Blue Spring. Measurements of water discharge near the mouth of the Little Colorado River made at times when the river was dry at the gaging station near Cameron, Arizona, (mile 45.5) indicate that the combined flow of the springs is constant. The average discharge, based on 10 measurements from June 1952 to May 1966, was 222 cubic feet per second. This discharge results in a contribution of 161,000 acre-feet of water annually and 547,000 tons of salt to the Colorado River.

Bright Angel Creek.--Bright Angel Creek enters the Colorado River just downstream from the hydrologic data station near Grand Canyon. The average annual water discharge (45 years of record) of Bright Angel Creek at its mouth is 25,410 acre-feet and is mostly from springs near the North Rim of the Grand Canyon. The base flow has been estimated as 15,000 acre-feet per year. Records of water quality indicate that the average dissolved-solids concentration is about 0.27 ton per acre-foot and that calcium, magnesium, and bicarbonate are the major dissolved constituents. The annual contribution of dissolved solids from Bright Angel Creek to the Colorado River is about 7,000 tons.

Tapeats Creek.--Tapeats Creek is fed by springs in its headwaters and by Thunder Spring, the source of water for its major tributary, Thunder River. Simultaneous measurements of water discharge at the mouth of Tapeats Creek and at the mouth of Bright Angel Creek indicate a good correlation of streamflow (R. B. Sanderson, written communication, 1963) and thus permit application of the long-term streamflow record for Bright Angel Creek to estimate the discharge of Tapeats Creek. By use of this correlation the average annual discharge of Tapeats Creek is estimated to be about 58,000 acre-feet.

Only few determinations of water quality of Tapeats Creek at its mouth have been made. These data indicate that the water is of the calcium, magnesium, bicarbonate type, and is of low mineralization.

The average dissolved-solids concentration of water at its mouth computed from the few measurements is about 0.2 ton per acre-foot. On this basis Tapeats Creek contributes about 12,000 tons of dissolved solids annually to the Colorado River.

Kanab Creek.--Kanab Creek has a drainage area of about 1,600 square miles, of which about 1,000 square miles is in southern Utah. A few miscellaneous measurements of water discharge and water quality have been made at the mouth of Kanab Creek. Calcium, magnesium, and sulfate are the principal dissolved constituents.

Based on these measurements the estimated base flow of Kanab Creek at its mouth is about 4 c.f.s. and the corresponding dissolved-solids concentration is about 1.5 tons per acre-foot. The minimum annual contribution of dissolved solids from Kanab Creek to the Colorado River on this basis is estimated to be 4,500 tons.

Havasu Creek.--Havasu Creek drains the Coconino Plateau south of the Colorado River and enters the river about 13 miles downstream from Kanab Creek. Two determinations of water quality at the mouth of Havasu Creek indicate that the water is of the calcium, magnesium, bicarbonate type and that its dissolved-solids concentration is about 0.5 ton per acre-foot. Ten measurements have indicated a base flow of about 65 c.f.s.

If the base flow of Havasu Creek is 65 c.f.s. (47,000 acre-feet per year) and the average dissolved-solids concentration is 0.5 ton per acre-foot, a minimum annual contribution of 24,000 tons of dissolved solids can be estimated to reach the Colorado River from Havasu Creek.

Other tributaries between Glen Canyon Dam and Lake Mead.--Many small springs and spring-fed tributaries also contribute dissolved solids to the Colorado River, but information about the water discharge and chemical quality of these inflows is sparse. In recent years, however, several parties of Interior Department scientists and engineers have made observations of water discharge and collected water-quality data during trips down the Colorado River.

Virgin River.--The dissolved-solids discharge of the Virgin River at Littlefield, Arizona, is about 350,000 tons per year (see Table 14). Although much of the water and dissolved solids is diverted for irrigation between Littlefield and the mouth of the river in Lake Mead, the dissolved solids eventually reach Lake Mead.

Of the springs which discharge into the Virgin River and its tributaries, the largest contributor of dissolved solids probably is LaVerkin Springs ("Dixie Hot Springs"). These warm (105-107° F.) springs discharge into the river in a reach several hundred yards long about 40 miles northeast of Littlefield, Arizona. Some of the springs rise in the bed of the river, and others discharge from the sides of the canyon walls in the Hurricane Fault zone.

In recent years several measurements of water discharge have been made just downstream from the springs when the entire flow of the Virgin River upstream from the springs was being diverted. These measurements ranged from 10 to 11 c.f.s. and indicate that the flow of the springs does not vary appreciably. The chemical quality of the combined spring inflow is also relatively constant.

The annual contribution of LaVerkin Springs is estimated as 7,700 acre-feet of water and 98,000 tons of dissolved solids which include principally sodium (26,000 tons), sulfate (22,000 tons), and chloride (38,000 tons).

Summary of contribution by springs and tributaries below Glen Canyon Dam.--Major springs and spring-fed tributaries annually contribute a minimum of almost 800,000 tons of dissolved solids to the Colorado River between Glen Canyon Dam and Lake Mead. Storm runoff in small tributaries in this reach of the Colorado River contribute an unknown, but probably much smaller, load to the river. The contribution of dissolved solids by major sources of inflow between Glen Canyon and Lake Mead equals about 10 percent of the average dissolved-solids load of the Colorado River at Lees Ferry. Springs in the lower Little Colorado River contribute about half of the measured increase in dissolved-solids discharge in the Colorado River between Lees Ferry and Grand Canyon.

LaVerkin Springs discharge almost 100,000 tons of dissolved solids annually to the Virgin River; this contribution is about one-fourth of the measured dissolved-solids discharge of the Virgin River at Littlefield, Arizona.

The annual dissolved-solids contributions of major springs, streams, and spring-fed tributaries to the Colorado River between Glen Canyon Dam and Lake Mead and to the Virgin River are summarized in Table C .

Table C

Contribution from major springs and tributaries between Glen Canyon and Hoover Dams

Source	Dissolved-solids discharge in thousands of tons per year
Paria River	30
Little Colorado River above Blue Spring	130
Springs in Lower Little Colorado River	550
Bright Angel Creek	7
Tapeats Creek	12
Kanab Creek (base flow)	4
Havasu Creek (base flow)	24
Total inflow in Colorado River (Glen Canyon Dam to Lake Mead)	757
LaVerkin Springs (inflow to Virgin River)	98
Total inflow to Colorado and Virgin Rivers	855

The minimum annual inflow of 855,000 tons from these sources results in an increase in dissolved-solids concentration of about 47 milligrams per liter (0.06 ton per acre-foot) in the Colorado River on the basis of an annual flow of 11 million acre-feet.

E. Agricultural Sources of Salinity

It is anticipated that development of new irrigation projects may increase the total dissolved solids in the Colorado River. Return flows from the irrigated lands pick up salts from the soils and underlying shales and transport them to the river system.

Studies in the basin thus far have been limited to a comparison of total dissolved solids in the inflowing water and the return flow water. Until recently no attempt had been made to determine losses of water or total dissolved solids by deep percolation, to detect underground aquifers that might be augmented with return flow, or to evaluate changes in chemical characteristics (other than total dissolved solids) resulting from development.

Studies prior to irrigation would be helpful, but they have not been made in most areas, so comparisons must be made when new land is added or new storage is made available. The Seedskadee Project area may present a comparison between "before" and "after" irrigation conditions after several years of full irrigation on the lands.

Salt balance conditions exist when the amount of dissolved solids carried off the land is equal to that amount added. Pickup of salt as used in this report represents an unbalanced condition shown by the increase of total dissolved solids load in the runoff over the total load in the applied water. This pickup from an area could result from natural sources, such as precipitation runoff, and/or irrigation return flows. Salt pickup chargeable to irrigation would be only that additional which occurs as a result of irrigation and should not include the amount of prior pickup off the land resulting from natural sources.

The small amount of data presently available gives indications of much variation in the amount of pickup from land due to irrigation. The estimated salt pickup in this report is based on values of zero and 2 tons from newly irrigated land. Zero or minimum conditions occur generally after initial leaching in areas where soils are loose and contain very little salt. The 2 tons per acre was selected as the higher end of the range for the average pickup over a project area. It was also assumed in this report no additional pickup would result from water applied to presently irrigated lands.

Quality of water studies have been made in several areas to determine storage and irrigation effects on water quality. Three of these worthy of mention are the Florida Project, Vernal Area, and Eden Project and are described in the following paragraphs:

1. Florida Project

Construction of the Florida Project was completed in 1965. The Lemon Reservoir on Florida River regulates the flow of the river for irrigation of 19,450 acres of land including 5,730 acres not previously irrigated and 13,720 acres in need of supplemental water.

In order to obtain quality information under preproject conditions, flow and quality data were collected at several points in the Florida Project area beginning in 1958. A study has been made of these data for the period 1958-63 to show the effect irrigation of these lands has on the quality of return flows leaving the project under the condition of no storage.

An attempt was made in this study to measure the effect of irrigation in the Florida area on the quality of water in the Animas River below its confluence with the Florida River. It was found that the difference in concentration, however, is scarcely discernible and is within the limits of error of measurement of both flow and quality.

Florida Project, Colorado

Year	Acre-feet or tons	Inflow	Outflow	Difference	Pickup (tons/acre)	Loss (tons/acre)
1958	A.F.	99,800	90,360	9,440		
	Tons	14,315	15,470	+1,155	0.08	
1959	A.F.	28,260	14,300	13,960		
	Tons	4,900	4,365	525		0.04
1960	A.F.	73,130	60,600	12,530		
	Tons	10,600	11,730	+1,130	0.08	
1961	A.F.	58,490	41,430	17,060		
	Tons	9,100	8,970	130		0.01
1962	A.F.	67,070	48,470	18,600		
	Tons	10,220	10,220	0	0	
1963	A.F.	45,800	33,750	12,050		
	Tons	7,889	7,100	789		0.06

From the above tabulation it is apparent that there has been a very small amount of pickup measured in the river downstream from the project. The concentration of total dissolved solids in the inflowing water ranges from 0.14 to 0.17 ton per acre-foot, and that of the outflowing water ranges from 0.17 to 0.30. About 13,720 acres were irrigated prior to construction of the project facilities.

Irrigation has been practiced for many years in the Florida area without adverse effects because of the extremely good water and the good drainage conditions.

The Florida Project soils and the adjoining Pine River Project soils are naturally low in salinity and alkalinity, and the amount of dissolved solids removed from these projects is about equal to the amount deposited indicating negligible pickup.

2. Vernal Area

A cooperative research study is being conducted in the Ashley Valley surrounding Vernal, Utah, by the Bureau of Reclamation with financial support provided by the Federal Water Quality Administration. This study is the initial phase of a large-scale research project entitled, "Prediction of Mineral Quality of Return Flow Water from Irrigated Land," which was initiated in the latter part of FY 1969. The primary objective of this project is to develop a digital simulation model which will accurately predict the quantity and quality of irrigation return flows from an entire irrigation project with known soil, groundwater, geologic and hydrologic characteristics. With such a model the water quality impact of a proposed irrigation development including its alternatives could be more accurately assessed. This would allow selection of the optimal design of proposed project features in order to minimize any adverse effects on water quality. Another application would be the evaluation of improvements of irrigation facilities and practices in established irrigated areas aimed at reducing present high salt contributions.

Ashley Valley was selected as the initial study area. Characterization studies of this area are currently underway. Initial runs of an elementary simulation model were made during 1970 using present data. The model will be refined and additional data collected during the next 2 years. Field studies are anticipated at other locations with various soil and geologic profiles to verify the model under a wide range of conditions.

Another project is directed toward the dual objectives of increasing the knowledge of the basic processes controlling the movement of salts in the soils and minimizing salt pickup by return flows. Utah State University initiated this project, "Quality of Irrigation Return Flow," during FY 1969 under a Federal Water Quality Administration research grant. With data from the laboratory and the greenhouse lysimeters, a digital simulation model was developed to predict the movement of salts with the corresponding changes in the quality of applied irrigation water in the soil. Using this model, on-farm irrigation practices and rate and timing of irrigation applications were planned to manage the salinity concentration of soil moisture within acceptable limits for the crop grown and at the same time minimize the salt pickup by the return flows.

The University established a 40-acre test farm near Vernal, Utah, in 1970 and will field test the laboratory model in 1970 and 1971. Results of these tests will be coordinated with the Bureau of Reclamation study in Ashley Valley.

Preliminary results indicate that it may be feasible to seasonally store salts contained in the irrigation water in the deeper soil zones during low streamflow periods and then flush these salts out during higher streamflows, thereby reducing the wide seasonal variations in stream salinity concentrations. With further refinement of the model it is expected that on-farm irrigation practices can be planned to obtain high irrigation efficiencies, a salt balance in the root zone, and also to minimize the pickup of additional salts from the soil profile by the return flows.

3. Eden Project

Quality of water data have been collected in the Eden Project area for the 14-year 1955-68 period. The amount of dissolved solids (as measured in Big Sandy Creek) picked up from project lands area has varied considerably over the years. Because of many variables from year to year in water supply, return flows, irrigated acreages, and other influencing factors, results from this study have not been conclusive. Collection of data should be continued for a few more years during which time attempts should be made for better controls of the influencing factors. Preproject data are very limited making preproject and postproject comparisons impractical.

4. Other Studies

Considerable variation in the effects of irrigation return flow on water quality is to be expected. Differences arise due to the size of the irrigated areas, the number of times the return flow is reused, properties of the soils and drainage area, number of years land has been irrigated, nature of aquifers, rainfall, dilution, temperature, irrigation methods, storage reservoirs, vegetation, and type of return flow channels.

Consumptive use, return flow, and salinity studies are now being conducted by Federal agencies in cooperation with State and local agencies. Some of the study areas are purposely being held small to achieve better control, but they will be as representative as possible of existing projects. The results pertaining to the quantity of return flow will be very helpful in estimating effects on water quality of return flows from larger areas where measurement of inflow and outflow is not always possible or practical.

Special studies in areas of the basin will continue to be made from time to time to determine water quality conditions, and studies of projects, such as Florida, Vernal Area, and Eden, should be repeated or continued in order to evaluate changes with time. The Seedskadee Experimental Farm area was monitored for quality of water for the period 1968 to July 1970. Data are presently being studied to see the effects of irrigation on quality of return flows. Projects which may need additional investigations include the Grand Valley (presently under canal lining study) and Uncompahgre Projects in Colorado and possibly some direct diversion projects along the Colorado River below Hoover Dam, such as Palo Verde Valley and the Colorado River Indian Reservations. An important consideration in quality studies is measurement of return flows because this information is a key factor in evaluating the adequacy of drainage and determining if salts are being accumulated or leached from a project.

F. Municipal and Industrial Sources of Salinity

Salt loads contributed to the Colorado River system by municipal and industrial sources are minor, totalling about 1 percent of the basin salt load. Future increases in salt loads from these sources are expected to be small relative to the total basin salt burden.

Most municipal and industrial wastes have relatively low salinity concentrations and complete elimination of such waste discharges would have little effect on salinity concentrations in the main river system. Since these wastes are point sources of salinity, control of a source could be achieved if salinity levels in the waste being discharged (i.e., industrial brines) warrant such control.

G. Summary of Sources of Salinity

Salinity concentrations in the Colorado River system increase severalfold between the high quality of headwater tributaries and the lower reaches of the river. This increase results from two basic processes--salt loading and salt concentrating. Salt loading, the addition of mineral salts from various natural and man-made sources, increases salinity by increasing the total salt burden carried by the river. In contrast salt concentrating effects result from concentrating the river salt burden in lessor volume of water when streamflow depletions are caused by consumptive use.

Salt loads are contributed to the river system by natural and man-made sources. Natural sources include diffuse sources such as surface runoff and diffuse groundwater discharges, and discrete sources such as mineral springs, seeps, and other identifiable point discharges of saline waters. Man-made sources include municipal and industrial waste discharges and return flows from irrigated lands.

BASIC STUDIES

Streamflow depletions contribute significantly to salinity increases. Consumptive use of water for irrigation is responsible for the largest depletions. Consumptive use of water for municipal and industrial purposes accounts for a much smaller depletion. Evaporation from reservoir and stream surfaces also produces large depletions. Phreatophytes, too, cause significant water losses by evapotranspiration, especially in the Lower Basin below Hoover Dam. Out-of-basin diversions are also a source of streamflow depletions.

PART V. EVALUATIONS OF EXISTING SALINITY CONDITIONS

A. Quality of Water Stations

A primary purpose of this report is to summarize water quality conditions for the Colorado River Basin. This part summarizes mineral quality under both historical and present conditions of water resource development and utilization. Anticipated changes in future mineral quality are discussed in Part VI. Other water quality parameters are discussed in Part IX.

Evaluations of the mineral quality of water in the basin are based on quality of water and streamflow records at 17 selected stations. Each station is considered to reflect flow and water quality conditions at its location. Records were generally available at each station for the time period considered by this report, 1941 to 1968. Where records were not available, missing data were estimated by correlation with other stations.

Basic data summarized in this report were primarily obtained from records of the Geological Survey developed by a continuing program for collection of water data which is supported in part by a transfer of funds from the Bureau of Reclamation.

Locations of the 17 key stations are shown on Figure 1 . Availability of flow and quality records for each station is shown on Figure 7 . The source and method of derivation of basic data for each of the stations are briefly discussed in the following sections.

1. Key Stations with Complete Records

Records of flow and water quality are available for all or nearly all of the 1941-68 period for the Green River at Green River, Utah (Station No. 4); Colorado River near Glenwood Springs, Colorado (Station No. 6); Colorado River near Cameo, Colorado (Station No. 7); Gunnison River near Grand Junction, Colorado (Station No. 8); Colorado River near Cisco, Utah (Station No. 9); and San Juan River near Bluff Utah (Station No. 11). Minor extensions only were needed to fill in short periods of record for a few of these stations. The Glenwood Springs gage was moved from above to below the Roaring Fork at the end of water year 1966. Subsequent Glenwood Springs gage records were adjusted by subtracting the Roaring Fork flows. All records were obtained from the Geological Survey.

2. Key Stations with Partial Records

Green River near Green River, Wyoming (Station No. 1).--Flow records are available at this station from April 1951 and quality records

Colorado River Basin
Flow and Quality of Water Records
1941 – 68

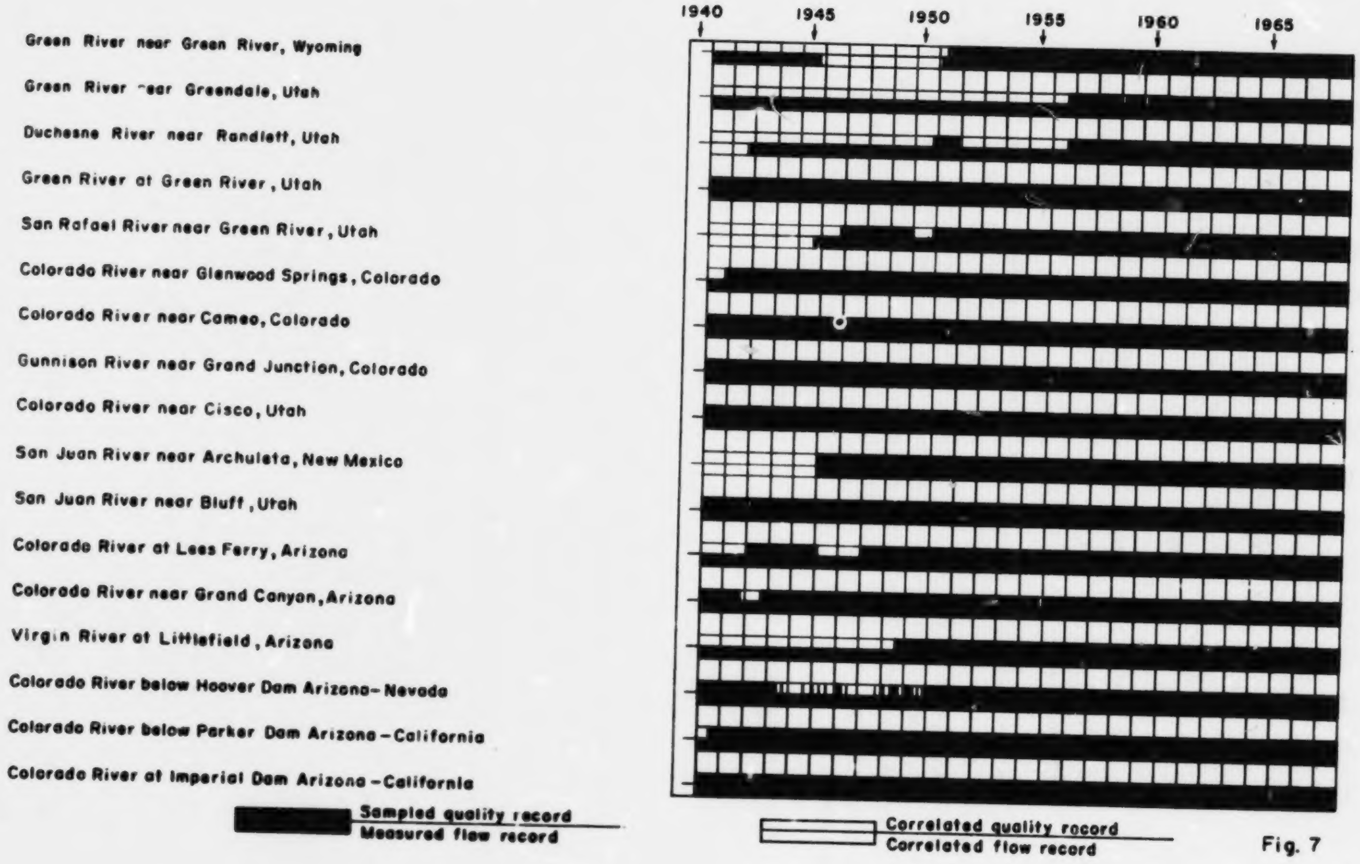


Fig. 7

from May 1951. The records have been extended back to 1941 by correlation with nearby stations.

Green River near Greendale, Utah (Station No. 2).--Flow measurements or comparable data are available for this station for the report period, but chemical quality data are available only for the years 1957 through 1968, inclusive. Extensive correlations with other available records on the Green River system were employed to develop estimates for dissolved solids.

Duchesne River near Randlett, Utah (Station No. 3).--Flow records have been obtained continuously since 1943 and quality data are available for 1951 and 1957 through 1968. Correlations with other stations in the Duchesne River system were employed to estimate the data for the missing period.

San Rafael River near Green River, Utah (Station No. 5).--Correlations were used to estimate flow at this gage from 1941 to 1945 after which measurements of flow were available. Quality sampling started in 1946 and is complete for the remainder of the study period except for 1950. Extensions of available data provided satisfactory estimates of mineral quality for the missing years.

San Juan River near Archuleta, New Mexico (Station No. 10).--For the period 1954 to 1968 flow and quality data presented are a combination of measurements obtained near Archuleta and at Blanco, New Mexico, with a few adjustments and correlations. Correlations were employed to estimate the data for 1941-54.

Colorado River at Lees Ferry, Arizona (Station No. 12).--This station has complete flow records available for the study period but lacks quality of water measurements for 1941, 1942, 1946, and 1947. Quality data for these years were estimated by extensive multiple correlations using data for the Colorado River near Cisco, Utah, and near Grand Canyon, Arizona; the Green River, Utah; and the San Juan River near Bluff, Utah.

Colorado River near Grand Canyon, Arizona (Station No. 13).--Flow records are available for the report period and chemical quality records are also available except for the period December 1942 to August 1943. Quality data for the period of missing records were estimated from records at upstream stations.

Virgin River at Littlefield, Arizona (Station No. 14).--Flow records are available for the report period, but quality data are available only from July 1949 to December 1968. Detailed correlations were employed to estimate the data for the missing period.

Colorado River below Hoover Dam, Arizona-Nevada (Station No. 15).--Discharge and quality records are available for the 1968 report period except for the period November 1944 to September 1950. Quality data for this period are based on specific conductance with chemical analyses only at intermittent intervals.

Colorado River below Parker Dam, Arizona-California (Station No. 16). --Flow records for the report period are available for the Geological Survey gage below Parker Dam. Quality data were obtained from the Metropolitan Water District of Southern California which takes samples at the Lake Havasu intake pumping plant.

Colorado River at Imperial Dam, Arizona-California (Station No. 17). --Flow records are available for the report period. Records from January 1941 through September 1942 are from the station, Colorado River near Picacho, California. Records from October 1942 through September 1960 are based on the combined records of discharge obtained at gaging stations on Colorado River at Yuma, All American Canal near Imperial Dam, Gila Gravity Main Canal at Imperial Dam, Yuma Main Canal at Laguna Dam, and North Gila Valley Canal at Laguna Dam less that of Gila River near Dome, Arizona. Records after September 1960 are based on the combined daily discharge of Colorado River passing Imperial Dam and at gaging stations on All American Canal near Imperial Dam and Gila Gravity Main Canal at Imperial Dam.

Quality data for the period January 1941 to 1943 were obtained from the U.S. Department of Agriculture salinity laboratory at Riverside, California. Quality data since 1943 were obtained from Geological Survey records and are based on data for the Yuma Main Canal below the Colorado River Siphon.

3. Other Quality of Water Stations

In addition to the key stations discussed above, there are many more points at which water quality data are obtained. Most of these sampling stations are operated by the Geological Survey; however, some are operated by other Federal, State, and private agencies.

The type of data obtained and the purpose of the sampling vary with each station. Many of the stations provide data for the special studies described in Part IV, Basic Studies.

B. Methods of Chemical Analyses

Published quality of water records consist of a combination of stream discharges with chemical analyses of stream water samples collected at more or less regular intervals. The reliability of the records depend on the accuracy of the streamflow records, the frequency of collection and representativeness of the samples, the stability of the samples during the storage periods prior to making of the analyses, the completeness and accuracy of the individual analyses, and the manner in which the individual samples are combined before analysis to represent increments of stream discharge.

Most of the chemical analyses of water samples which provided the water quality data were made in the laboratories of the Geological Survey at Washington, D.C., Albuquerque, N. Mex., and Salt Lake City, Utah, using standard procedures by chemists specifically trained in water analysis. During the 28-year period considered there were numerous changes in laboratory techniques and procedures mostly due to introduction of new instrumental methods. New procedures were adopted only after careful investigation to insure results consistent with those obtained previously. Some of the quality of water records are based on analysis of samples by Bureau of Reclamation laboratories. Bureau of Reclamation results and methods have been checked by the Geological Survey to insure comparable records. Analyses by the Metropolitan Water District have been made by standardized procedures and appear to be comparable with analyses by the Geological Survey. It is probable that errors in the load computations due to errors in chemical analyses are less than those due to changes in the samples upon storage, inaccuracies in sampling, or inaccuracies in the determination of stream discharges.

C. Historic Mineral Quality

1. Total Dissolved-Solids Concentrations

Historic streamflow, total dissolved solids (salinity) concentrations, and salt-load data for the 17 key stations for the 1941-68 period of record are presented in Tables 1 to 17 with each table number corresponding to a station number.

To simplify tabulation, monthly values of flow and total dissolved solids loads were rounded to the nearest 1,000. This resulted in some differences between the recorded and the computed monthly concentrations when the flows were low, for example, below 1,000 acre-feet in the San Rafael and Duchesne Rivers. Similarly, minor differences from published data in monthly concentrations occur in isolated instances in the flow and quality tables for the other stations.

The addition of quality of water data for 1967 and 1968 produced little change in long-term averages in comparison to the 1941-66 period. Six of the stations show no change; at six, the concentration increased by 0.01 ton per acre-foot, and at three it increased by 0.02 ton per acre-foot. The average concentration for the Virgin River station for the period 1941-66 was 2.26 tons per acre-foot while the average concentration for the period 1941-68 was 2.29 tons per acre-foot, and the San Rafael River station concentration was increased from 2.2 to 2.3 tons per acre-foot.

EVALUATIONS OF EXISTING SALINITY CONDITIONS

The water quality at the Lees Ferry and the four other key stations on the Lower Colorado River has been affected by abnormal conditions during the 1959-68 period because of low runoff in 1959, 1960, and 1961 and the filling of Lake Powell during the period 1963-68. Figure 8 shows the historical weighted average salinity concentration for these five stations.

During the first year of storage in Lake Powell in 1963, the flow at Lees Ferry was reduced to 1,384,000 acre-feet with a salinity concentration of 1.27 tons per acre-foot. The average concentration for the 1941-68 period was 0.75 ton per acre-foot.

The salinity concentration increases between the Lees Ferry station and the Grand Canyon station primarily as a result of the additions of a large salt load from the Blue Springs located on the Little Colorado River. The 1963 flow at the Grand Canyon station was 1,384,000 acre-feet with a salinity concentration of 1.41 tons per acre-foot. The previous low flow was 4,186,000 acre-feet in 1934 with a salinity concentration of 1.32 tons per acre-foot. It is interesting to note that the 1963 concentration was only 0.09 tons per acre-foot higher than the 1934 concentration.

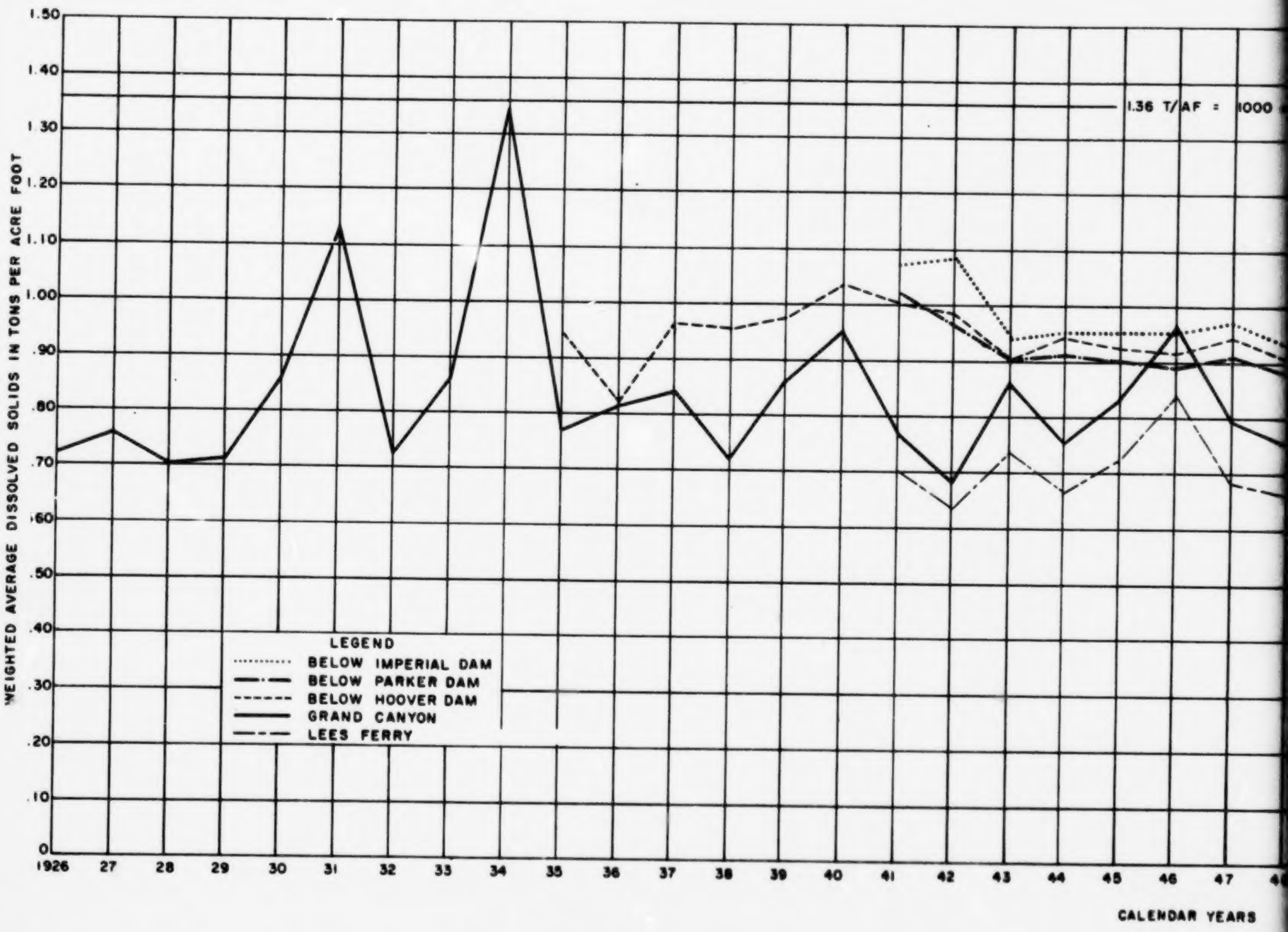
The Grand Canyon station has the longest water quality record on the Colorado River, 1926 to 1968. It is also of interest that the average salinity concentration for the period 1941-68 is only slightly higher than the average salinity concentration for the period 1926-40, 0.84 and 0.81 ton per acre-foot, respectively.

Generally the salinity concentration increases at each succeeding downstream station as a result of depletions by diversions, reservoir and stream evaporation, and consumptive use by irrigated crops and phreatophytes, and by salt loading by inflowing springs, streams, solution of salts from the streambeds and reservoir basins, and possibly by irrigation return flows. The flows of the Bill Williams River often dilute the flow of the Colorado River in Lake Havasu which sometimes results in a decrease in the salinity concentration from the Below Hoover Dam station to the Below Parker Dam station. Figure 8 shows the concentration changes between the five lower stations on the Colorado River. Note also that Lake Mead has a dampening and delaying effect, about 2 years, on the salinity concentrations at the downstream stations. This is especially noticeable for the high salinity concentrations of 1963 at the Lees Ferry and Grand Canyon stations.

2. Ionic Loads

In addition to the total dissolved-solids concentration of a water supply, the relative chemical composition may be of significance for some types of water use. Annual summary of ionic loads in tons-equivalent for the 1941-68 period have been included in this report to further depict quality conditions at six key stations: Green River at Green River, Utah;

WEIGHTED AVERAGE DISSOLVED SOLIDS CONCENTRATIONS, CO



A

COLORADO RIVER BELOW LEES FERRY, ARIZONA

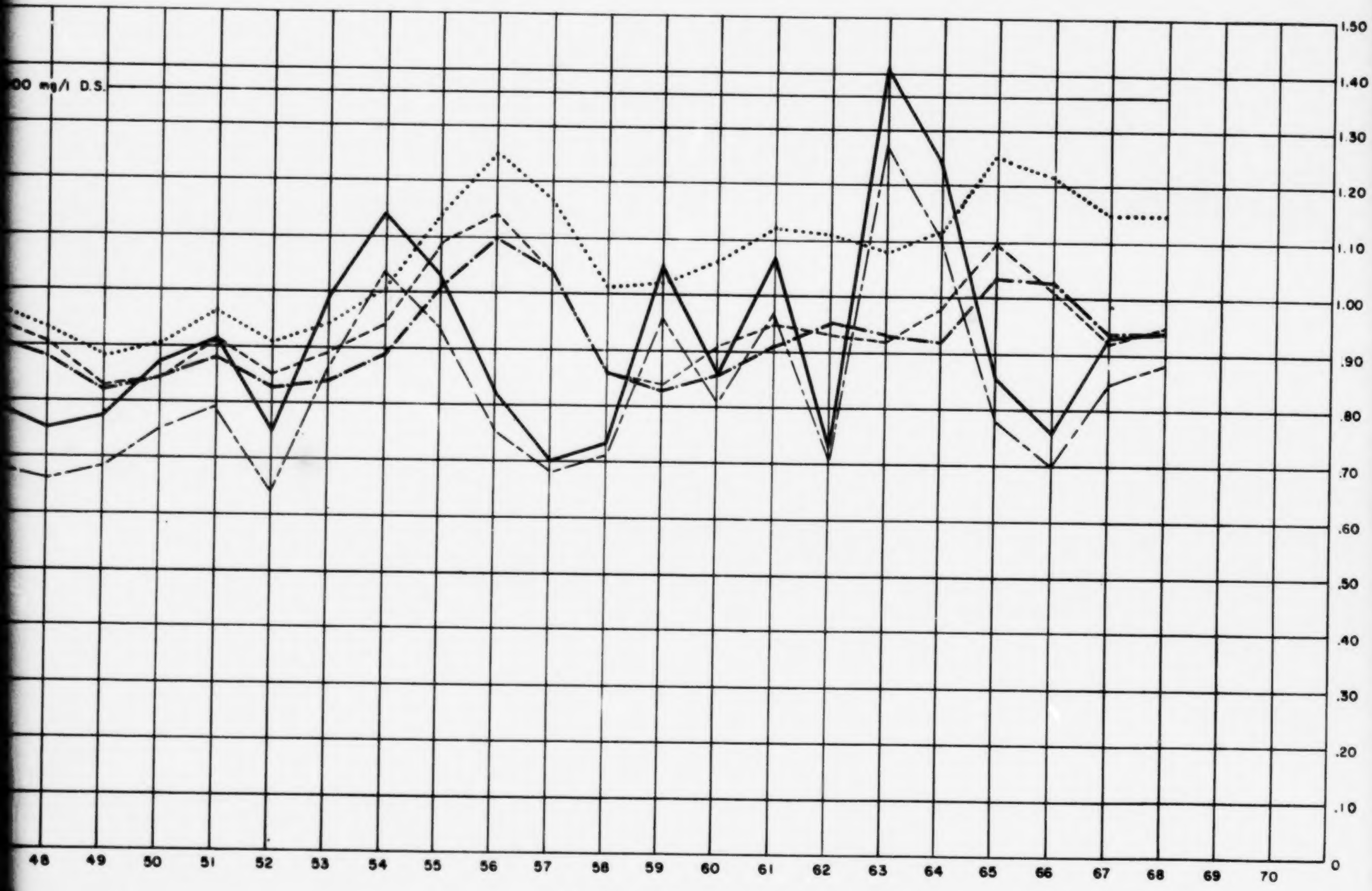


Figure 8

B

Colorado River near Cisco; San Juan River near Bluff; Colorado River at Lees Ferry; Colorado River below Hoover Dam; and Colorado River at Imperial Dam. Tables 20-25 give ionic loads for the six principal ions: calcium, magnesium, sodium, bicarbonates, sulfates, and chlorides. The specific conductance, sodium adsorption ratio, and total dissolved-solids concentrations are also shown. At each station the amount of potassium is negligible, and carbonates are generally not present.

D. Present Modified Condition

Present modified flow, as defined for this report, is the flow expected at any point with all upstream existing projects in operation for the full period of study. It was estimated at the various stations by assuming a recurrence of past water supply conditions and by deducting from the annual historical flows the depletions that would have resulted from the operation of all upstream projects constructed and in operation since that year. Besides adjusting for minor projects a correction was made for the historical operation and evaporation of the Colorado River Storage and Fontenelle Reservoirs in order to obtain unregulated flows at each station. Estimated present evaporation was then deducted to obtain present modified flows. Present evaporation from the Colorado River Storage Project and Fontenelle Reservoirs was estimated to be 649,000 acre-feet per year. This would include evaporation from Lake Powell of 533,000 acre-feet, Flaming Gorge 54,000 acre-feet, Navajo 30,000 acre-feet, Curecanti Reservoirs 15,000 acre-feet, and Fontenelle Reservoir 17,000 acre-feet. These are average figures which were chosen to represent present conditions rather than using the 1968 historical evaporation since a single year record could show an above-or-below normal condition. Present evaporation of the Lower Basin Reservoirs was assumed the same as historical since these reservoirs have been operating for a number of years.

Historical flows since 1941 have been affected by the transmountain diversions of the Colorado-Big Thompson Project, Duchesne Tunnel of Provo River Project, Roberts Tunnel of the City of Denver, and a number of small in-basin developments. More recently the Collbran, Paonia, Smith Fork, Silt, Florida, Hammond, and Emery County Projects and Vernal Unit of Central Utah Project have come into operation. Also, evaporation from the storage units--Glen Canyon, Flaming Gorge, Navajo, Curecanti and Fontenelle--is now in effect along with the Hayden Steamplant, Utah Construction Company steamplant, expansion of Hogback Indian lands, and the municipal and industrial uses in Wyoming. The depletions from these projects have been extended back to 1941, from the time they became operational, so that when new projects are imposed on the present modified condition the anticipated effects can be estimated. In the near future several projects now under construction will become operational. The addition of these new depletions results in slight increases in dissolved-solids concentrations under present modified conditions over the 1941-66 period.

EVALUATIONS OF EXISTING SALINITY CONDITIONS

Quality data for present modified conditions were computed by taking into consideration the weighted average of the concentrations of total dissolved solids for the various transmountain diversions. The change in dissolved solids resulting from the in-basin developments were computed on the basis of an assumed pickup of 2.0 tons of dissolved solids per acre of irrigated land and a depletion of 1.5 acre-feet of water per irrigated acre. Modified flows and quality for present conditions are shown in Table 18.

As in previous reports, present modified flows are used as a basis for developing the anticipated effect of the participating projects and other developments.

Following is a description of the storage units, now constructed, for which the evaporation losses were considered as depletions in the computation of present modified flows.

1. Glen Canyon Unit

The Glen Canyon Dam is located on the Colorado River in Arizona 4 miles south of the Utah-Arizona boundary and 15 miles upstream from Lees Ferry. The bulk of the reservoir lies in Utah. At a normal water surface elevation of 3,700 feet m.s.l., Lake Powell would extend 186 river miles up the Colorado River and 71 miles up from the mouth of the San Juan River. River mile 71 on the San Juan River is 133 river miles from Glen Canyon Dam. This 27,000,000-acre-foot reservoir will regulate the flow of the river for compact delivery purposes and for power generation and thus permit exchanges for upstream consumptive use of the water. Fish and wildlife conservation and recreation will also be of major significance. Storage commenced March 31, 1963, in Lake Powell.

2. Flaming Gorge Unit

This storage unit is located on the Green River in northeastern Utah and southwestern Wyoming. The primary purposes of the Flaming Gorge Unit are the regulation and storage of flood flows of the Green River and the generation of hydroelectric power. The reservoir has a storage capacity of 3,789,000 acre-feet. The stored water assists in complying with the terms of the Colorado River Compact and will, by exchange, furnish an irrigation supply for the participating projects in the Upper Basin States. In addition there will be benefits from fish and wildlife conservation and recreational facilities. Storage commenced November 1, 1962, at Flaming Gorge Reservoir, and from the records taken immediately below the dam it appears that the reservoir releases will be more uniform in quality than uncontrolled streamflow prior to reservoir construction.

3. Navajo Unit

The Navajo Dam and Reservoir are located on the San Juan River in northwestern New Mexico and southwestern Colorado. Total storage capacity of the reservoir is 1,709,000 acre-feet. This reservoir regulates the flow of the river for irrigation of the Hammond Project, the Navajo Indian Irrigation Project, and for other uses including by exchange potential uses above the reservoir and transmountain diversions to the San Juan-Chama Project. It also helps regulate the flows of the Colorado River at Lees Ferry. Other purposes include recreation, sediment control, fish and wildlife propagation, and flood control. Storage began July 1, 1962, and the effect on quality is recorded at the Archuleta station below Navajo Dam.

4. Curecanti Unit

Facilities of the Curecanti Unit, located in west-central Colorado, include the Blue Mesa, Morrow Point, and Crystal Dams, Reservoirs, and Powerplants. The primary purposes are regulation and storage of flood flows of the Gunnison River and generation of hydroelectric power. In addition benefits will be provided to recreation, fish and wildlife conservation, and irrigation. The reservoirs of the Curecanti Unit will help regulate the flows of the Colorado River at Lees Ferry. The storage capacity provided is 941,000 acre-feet at Blue Mesa, 117,000 acre-feet at Morrow Point, and 27,000 acre-feet at Crystal Reservoir with total reservoir evaporation losses estimated to average 15,000 acre-feet annually for all three units. Storage was initiated late in 1965 at the Blue Mesa Reservoir and on January 24, 1968, at the Morrow Point Reservoir. Construction has not yet been initiated on Crystal Dam, and it possibly should have been considered as a future development, but since the annual evaporation will amount to only about 300 acre-feet its effect is insignificant.

It is expected that operation of the Curecanti Unit on the Gunnison River will improve the quality of the Colorado River below Grand Junction during the late summer months.

5. Fontenelle Reservoir

Fontenelle Reservoir, located on the Green River above Green River, Wyoming, has a storage capacity of 345,000 acre-feet and regulates the flow in the Green River above Flaming Gorge Reservoir. It will be used to supply water to the Seedskadee Project lands after the project is completed.

PART VI. ANTICIPATED EFFECTS OF ADDITIONAL DEVELOPMENTS

In order to estimate the probable effect of the authorized or contemplated developments on the quality of water at certain points along the Colorado River, the developments have been generally listed in downstream order. By means of operation studies the estimated effects of each development can be shown at the pertinent stations. These results are tabulated in Table 18 for the new period of record used in this report. The table was computed on the basis of the 1941-68 average annual flow and total dissolved solids. An additional station, "Colorado River above Parker Dam," was included in the table only for purposes of clarification and maintaining continuity in computations. It should be noted that future concentrations were estimated without consideration to possible future control measures.

The anticipated future conditions evaluated in Table 18 would result from the construction of the Colorado River Basin Projects and non-Federal developments. Pickup of dissolved solids from newly irrigated lands has been computed for two assumed conditions, zero and 2 tons per acre pickup.

Following is a discussion of the various projects including a brief description of the physical conditions for each development authorized or contemplated for authorization and the anticipated effect of each on the quality of water at appropriate key stations. It should be recognized that the acreages and depletions as listed could change with change of plans on some of the contemplated projects. The figures presented below and in Table 19 are those which were current at the time of writing this report. In addition to the developments listed, a number of smaller private industrial developments either under construction or contemplated will result in certain depletions and will have some effect on water quality.

The effects of all upstream developments are carried on down to and including Imperial Dam.

A. Description of Projects

1. Above Green River near Green River, Wyoming

Seedskadee Project.--This multipurpose project is located adjacent to and will divert water from the Green River in southwestern Wyoming to irrigate about 58,000 acres of land. Municipal and industrial water, recreation, and fish and wildlife protection are other purposes of the project. A depletion of 145,000 acre-feet is anticipated when the project is fully developed. Fontenelle Dam and Powerplant are now complete, but irrigation of the project lands is awaiting results from the development farm now undergoing tests in the project area. The irrigation of 15,000 acres is in question until a determination has been made of the effect the mining of trona will have on land subsidence and irrigation development. The Seedskadee area has not been previously irrigated except for the land in the experimental development farm so it affords an opportunity to determine the effect irrigation has on water quality under the given soil and crop conditions. Present depletions amount to about 20,000 acre-feet including evaporation.

Industrial developments in southwestern Wyoming.--These include Westvaco, Green River and Rock Springs municipal and industrial, Stauffer, Allied Chemical, and other industries. They will consumptively use another 86,000 acre-feet above Green River, Wyoming, when fully developed. The only industry in Wyoming below the Green River near Green River, Wyoming, gage would be Utah Power & Light Company's steam-electric powerplant on Hams Fork which will consumptively use about 8,000 acre-feet.

The effect of Seedskadee irrigation project and industrial developments on water passing the Green River, Wyoming, gage would be an increase in concentration from 0.44 to 0.52 ton per acre-feet if no dissolved solids are leached from the land; and if 2 tons per acre are picked up, the concentration would increase to 0.63 ton per acre-foot.

2. Between Green River near Green River, Wyoming, and Green River near Greendale, Utah

Lyman Project.--This is a multipurpose project located in southwestern Wyoming. Project facilities consist of two dams and reservoirs. One will be located at the Meeks Cabin site on the Blacks Fork in Wyoming and will provide 33,000 acre-feet of storage capacity. The other will be located at the China Meadows site of the East Fork of Smith Fork in Utah and will provide 13,000 acre-feet of storage capacity. The project will have the primary purpose of providing supplemental water to 42,674 acres of existing farmland along with fish and wildlife and recreation benefits. Construction of Meeks Cabin Dam is nearing completion. This project will give an opportunity to study the effect on quality of adding supplemental water to lands already irrigated. The resulting new depletion will be 10,000 acre-feet.

Utah Power & Light Co. and Others.--This steam powerplant is at Kemmerer, and it is anticipated that depletions of this and other industrial developments will amount to about 8,000 acre-feet. (See description above under "Industrial developments in southwestern Wyoming.")

These projects, together with those above the Green River near Green River, Wyoming, gage, would cause an increase in concentration of the water at the Green River near Greendale gage of from 0.59 ton per acre-foot at present to 0.69 and 0.78 ton per acre-foot for zero ton per acre and 2 tons per acre pickup from newly irrigated land, respectively.

3. Above Duchesne River near Randlett

Central Utah Project (Bonneville Unit).--The Bonneville Unit will include a transmountain diversion of water from the headwaters of the Duchesne River in the Uinta Basin portion of the Colorado River Basin to the Bonneville Basin. Related developments of local water sources will be made in both basins. The project will develop water for irrigation, municipal and industrial use, and power production. It will also provide benefits to recreation, fish and wildlife, flood control, water quality control, and area redevelopment.

The net depletion to the Green River will be 166,000 acre-feet of which 136,000 is exported to the Bonneville Basin and the balance is depleted in the Uinta Basin.

Central Utah Project (Upalco Unit).--The Upalco Unit will be located in Duchesne County near Roosevelt, Utah. The plan of development is primarily to provide supplemental irrigation water for Indian and non-Indian lands along Lake Fork River and to enhance recreation, fish, and wildlife while maintaining flood control. The mean annual stream depletion is estimated to be about 10,000 acre-feet.

Central Utah Project (Uintah Unit).--The Uintah Unit of Central Utah Project will provide a full supply to irrigate 7,800 acres of new lands and supplemental water to other lands on the south slope of the Uinta Mountains in the Uinta and Whiterocks Rivers drainage areas. The new annual depletion will be about 30,000 acre-feet.

The increase in concentration from present to future at this station would be from 0.96 ton per acre-foot to 1.73 and 1.81 tons per acre-foot for zero and 2 tons per acre pickup, respectively.

4. Between Green River near Greendale, Duchesne River near Randlett, and Green River at Green River, Utah

Four County, Colorado.--This non-Federal development, as proposed, would divert 40,000 acre-feet of water through the Continental Divide for use in Colorado. The water would be transported from the headwaters of the Yampa River through Rabbit Ears Pass to the North Platte Basin, from which basin an equivalent amount of water would be directed by exchange over Willow Creek Pass into the Colorado River drainage, thence by transbasin diversion to Lafayette, Erie, Broomfield, Brighton, Thornton, and Ft. Lupton.

Hayden Steamplant.--This plant in Colorado now using 4,000 acre-feet will eventually require 16,000 acre-feet of water.

ANTICIPATED EFFECTS OF ADDITIONAL DEVELOPMENTS

Cheyenne, Wyoming.--The city of Cheyenne diverts water from the Little Snake River to a tributary of the North Platte in exchange for water diverted from Douglas Creek for municipal use by the city of Cheyenne. This transmountain diversion is now using about 7,000 acre-feet and will ultimately deplete the Colorado River by an additional 24,000 acre-feet.

Savery-Pot Hook Project, Colorado-Wyoming.--This project is located in the Little Snake River Basin in southern Wyoming and northwestern Colorado. The authorized project plan calls for construction of an 18,600-acre-foot-capacity reservoir on Savery Creek and a 65,000-acre-foot-capacity reservoir on Slater Creek. This storage will make possible the irrigation of 17,920 acres of new land and will provide supplemental water for land presently irrigated. Plan modifications are being considered in the definite plan studies now underway. Depletion of the Little Snake River by the Savery-Pot Hook Project would amount to 27,000 acre-feet annually.

Central Utah Project (Jensen Unit).--This unit will be located along the Green River east of Vernal in Uintah County in Uinta Basin, Utah. Storage of water in Tyzack Reservoir on Brush Creek together with pumping from the Green River will supply 440 acres of new land and 3,640 acres of presently irrigated lands. Approximately 15,000 acre-feet of water is anticipated to be depleted by this project.

The estimated increase in concentration at the Green River, Utah, gage from present to future would be 0.64 ton per acre-foot to 0.73 and 0.78 ton per acre-foot for the zero and 2 tons per acre pickup, respectively. Projects affecting the flows would include all developments above the gage.

5. Above San Rafael River near Green River, Utah

With inclusion of the Emery County Project under present modified conditions, the only anticipated future effect would be steam-electric plants depleting about 5,000 acre-feet of water and replacing an estimated 4,000 acres of presently irrigated lands with industries.

6. Above Colorado River near Glenwood Springs

Denver, Englewood, Colorado Springs, and Pueblo, Colorado.--Expansion of municipal supplies for these four cities will eventually deplete the Colorado River by 216,000 acre-feet above present uses. These are transmountain diversions from the Blue, Fraser, and Eagle Rivers in the headwaters of the Colorado River. The diversions would vary according to runoff each year.

ANTICIPATED EFFECTS OF ADDITIONAL DEVELOPMENTS

M&I--Green Mountain.--Water stored in Green Mountain Reservoir will be released for industrial use in the vicinity of Kremmling, Colorado, and in Garfield County, Colorado. This depletion will ultimately be about 12,000 acre-feet.

Homestake Project, Colorado.--The Homestake Project in Colorado, under construction by the cities of Aurora and Colorado Springs, will divert an average of 49,000 acre-feet annually to the eastern slope from the headwaters of the Colorado River although the diversions will vary from year to year.

The above depletions would increase the dissolved-solids concentration at Glenwood Springs by 0.08 ton per acre-foot under either condition of pickup.

7. Between Colorado River near Glenwood Springs and Colorado River near Cameo

Independence Pass Expansion.--This development consists of enlarging and lining an existing collection system on the western slope in Colorado with provisions for winter operation. The water will be collected from the headwaters of Roaring Fork for transmountain diversion to the Arkansas River Basin. The new depletion to the Colorado River will be about 14,000 acre-feet annually with possible storage in enlarged Twin Lakes Reservoir.

Fryingpan-Arkansas Project.--Construction is still continuing on this project. This transmountain diversion project will transfer water from the headwaters of the Colorado to the Arkansas River. It is a multipurpose development to supply supplemental irrigation water, municipal water, and water for power production. In addition the project will also control floods originating above pueblo, retain sediment, preserve fish and wildlife, and provide recreation opportunities. The average annual depletion will be 70,000 acre-feet, including 1,000 acre-feet of evaporation from the Ruedi Reservoir on the west slope.

M&I--Ruedi Reservoir, Colorado.--Storage rights in Ruedi Reservoir would permit the use of 38,000 acre-feet for oil shale development along the Colorado River in Colorado. The water would be stored in Ruedi Reservoir on the Fryingpan River and then released through natural channels to the points of use in the oil shale areas. A possible future alternative use for all or part of this water would be for irrigation purposes.

West Divide Project, Colorado.--The West Divide Project will provide 115,600 acre-feet of water for irrigation and 77,500 acre-feet for municipal and industrial use. The irrigation water will supply nearly 19,000 acres of new land and a supplemental supply to 21,000 acres of land presently irrigated. The new depletion of Colorado River water will be 76,000 acre-feet annually. Project water will be obtained from a series of

Colorado River tributaries south of the river in west-central Colorado with most of the storage planned for the 105,000-acre-foot Placita Reservoir.

The above-described projects, together with those above the Glenwood Springs station, would increase the concentration at the Cameo Station from 0.60 ton per acre-foot under present modified conditions to 0.73 and 0.75 ton per acre-foot for future conditions assuming zero and 2 tons pickup per acre, respectively.

8. Above Gunnison River near Grand Junction

Fruitland Mesa Project, Colorado.--This project is located in western Colorado in Gunnison River Basin. A 48,235-acre-foot storage reservoir on Soap Creek and diversion from Crystal and Curecanti Creeks would provide water needed for 15,870 acres of newly irrigated land and 7,000 acres of land now irrigated. Project uses will increase Colorado River depletions by 28,000 acre-feet per year.

The project water for irrigation use has been determined by laboratory analysis to be of excellent quality. Likewise, most of the return flow considered as part of the project water supply will be diluted with higher quality direct flow.

Bostwick Park Project, Colorado.--This small project is located in Montrose and Gunnison Counties in west-central Colorado. Storage regulation will be provided by a 13,520-acre-foot reservoir on Cimarron Creek, a tributary of the Gunnison River. Only 1,610 acres of new land will be irrigated and the increased depletion to the Colorado River will be 4,000 acre-feet. Some additional water will be provided to land now irrigated. The water of Cimarron Creek has been determined by laboratory analysis to be of good quality for irrigation. The Bostwick Park Project is now under construction and is scheduled for completion in the latter part of 1970.

Dallas Creek Project, Colorado.--The Dallas Creek Project will develop water of the Uncompahgre River and tributaries for irrigation and municipal and industrial use. The project will provide water for 15,000 acres of new land and supplemental water for 8,700 acres of land presently irrigated. Depletion of the Colorado River will amount to 37,000 acre-feet annually.

The project water supplies will be suitable in quality for irrigation and for municipal and industrial uses as well.

At the Gunnison River near Grand Junction station the concentration would be increased by 0.04 ton per acre-foot with no pickup and 0.08 with 2 tons per acre pickup.

9. Between Colorado River near Cameo, Gunnison River near Grand Junction, and Colorado River near Cisco, Utah

Dolores Project, Colorado.--The Dolores Project will divert water from the Dolores River Basin to the San Juan drainage for the irrigation of 61,000 acres. Some 32,000 acres will be new land; the remaining 29,000 acres of land are now receiving a partial supply. This project will divert 140,000 acre-feet of water from the Dolores River of which 8,700 acre-feet will be depleted and the balance returned to the San Juan River.

Return flows from lands in the Montezuma Valley are presently used for irrigation of land in McElmo Canyon outside the project area. Analyses show these flows have relatively high concentrations of soluble salts. They are successfully used for irrigation, however, because of internal drainage characteristics of the soils. The salt concentration of these flows is not expected to increase with project development.

San Miguel Project, Colorado.--The San Miguel Project will regulate flows of the San Miguel River for irrigation, municipal and industrial use, recreation, flood control, and fish and wildlife conservation. The project will supply water to 26,000 acres of new land and 12,500 acres of land now receiving a partial supply. Depletion of the Colorado River will be about 85,000 acre-feet.

The Colorado River near Cisco gage is affected by all upstream developments on the Colorado, Gunnison, and Dolores Rivers and their tributaries. These transmountain diversions and in-basin projects increase the concentrations from 0.91 to 1.08 tons per acre-foot with no pickup and to 1.12 with 2 tons per acre pickup.

10. Above San Juan River near Archuleta

San Juan-Chama Project.--Construction is underway on this transmountain diversion project with delivery of water to the Rio Grande Basin expected to be initiated in 1971. The project will divert an average of 110,000 acre-feet annually from the headwaters of the San Juan River across the Continental Divide to the Rio Grande Basin. The effect of this depletion on the Colorado River will be that some dissolved solids will be transported out of the basin and less high quality water will be available downstream for dilution of lower quality water.

The water will be used in New Mexico for municipal and industrial developments and for irrigation.

Navajo Indian Irrigation Project.--Construction activities are underway on this project, but completion of construction and delivery of water are several years away. The direct diversion of 508,000 acre-feet of water annually from the Navajo Reservoir to 110,000 acres of lands south of the San Juan River is contemplated. None of these lands are presently irrigated and the effect of irrigation on the quality and quantity of return flow is difficult to predict.

There will be times under ultimate basin development when the San Juan Valley lands below Farmington, New Mexico, will be dependent largely upon return flows for their supply of irrigation water. There are very little data upon which to base estimates of the quality of the return flow. Miscellaneous records from the San Juan, Animas, and La Plata Rivers indicate some periods of low flow water of questionable quality, especially from La Plata River system where some of the lands are known to be of marine origin. Practically all of the lands in the Navajo Indian Irrigation Project which would contribute return flow at the Hogback, however, are of fresh water origin with low salinity and alkalinity as determined by soil borings. To ascertain the quality of return flow with any degree of certainty, additional field data will be necessary prior to completion of definite plan investigations. The estimated depletion is 250,000 acre-feet annually.

The effect of the San Juan-Chama and Navajo Indian Irrigation projects in the quality of water at this station would be small since the water is presently of very good quality and the station is located only a short distance below the Navajo Dam where there would be no return flows. The increase in concentration would be from 0.23 ton per acre-foot present to 0.24 ton per acre-foot for both zero and 2 tons per acre pickup.

11. Between San Juan River near Archuleta and San Juan River near Bluff

Animas-La Plata Project, Colorado-New Mexico.--The Animas-La Plata Project will develop flows of the Animas and La Plata River systems for irrigation, municipal and industrial use, recreation, and fish and wildlife conservation. The project will supply water to 46,500 acres of new land and 25,600 acres of presently irrigated land. The new land will include 17,200 acres of Indian land. The total new depletion will amount to nearly 146,000 acre-feet. Project features include four storage dams, lengthy canals, and several diversion dams.

Preliminary water quality studies indicate that irrigation will not present any particular quality problem, and the additional return flow at the state line may be somewhat improved over the present.

Expansion Hogback.--This direct diversion to Indian lands adjacent to the San Juan River will result in a new depletion of about 10,000 acre-feet annually. These lands, in the vicinity of Shiprock, New Mexico, have been developed in small blocks by the Bureau of Indian Affairs over a period of years with further expansion planned for the future. The seepage and return flows return direct to the San Juan River, but the quality of these flows has not been determined.

ANTICIPATED EFFECTS OF ADDITIONAL DEVELOPMENTS

Utah Construction Company.--In northwestern New Mexico, a large steam-electric powerplant, which has been partially completed by Utah Construction Company for the Navajo Indian Tribe and the Arizona Power Authority, is now using 15,000 acre-feet out of an estimated 40,000 acre-feet when the plant is complete.

The San Juan River near Bluff gage would be affected by all developments on the San Juan River above the gage. Especially notable would be return flows from the Indian Irrigation Project. The result would be an increase from 0.63 to 0.91 and 1.25 tons per acre-foot, respectively, for the zero and 2 tons per acre pickup from new irrigated lands.

12. Between Green River at Green River, Utah, San Rafael River near Green River, Utah, Colorado River near Cisco, San Juan River near Bluff, and Colorado River

Resources, Incorporated, Utah.--Resources, Incorporated, proposed to construct a large powerplant in Utah near Lake Powell using coal from the Kaiparowits Plateau for fuel and water from Lake Powell for plant operation. The expected annual depletion to the Colorado River would be 102,000 acre-feet, based on the company's application to the State of Utah for that much water. The exact date of this depletion is not known at present.

M&I in Arizona.--The Upper Colorado River Compact allocated 50,000 acre-feet to Arizona from the Upper Colorado River system and of that amount about 15,000 acre-feet is presently being used.

The remaining 35,000 acre-feet will be used in that portion of Arizona within the Upper Basin and would be diverted above Lees Ferry with most of it being used by the Navajo Powerplant at Lake Powell.

The total depletions and salt pickup above Lees Ferry increase the concentration at the Lees Ferry gage from 0.84 to 1.01 tons per acre-foot with no pickup, and with 2 tons of pickup the concentration increases from 0.84 to 1.09 tons per acre-foot.

13. Above the Virgin River at Littlefield, Arizona

Dixie Project, Utah.--The recently authorized Dixie Project will, through construction of a multipurpose dam on the Virgin River, provide a full water supply to 6,900 acres of new land and a supplemental water supply to 10,000 acres of existing irrigated land. About 5,000 acre-feet of municipal and industrial water will be provided to the city of St. George. Cedar City, Utah, can also exercise an existing agreement to divert up to 8,000 acre-feet of water out of the basin from upper tributaries.

A principal concern of the downstream users in Arizona and Nevada will be in regard to the effect of project operations on water quality and the amount of flood waters available for leaching purposes. In this regard the effect of the highly mineralized LaVerkin Springs, which enter the river above the proposed Virgin River Dam, is of considerable importance.

The estimated increased depletion of the Virgin River due to total project development will be 48,000 acre-feet per year. Disposal of the waters of the LaVerkin Springs would increase the estimated annual depletion by the quantity of water removed from the river system. The average annual flow of the Virgin River at Littlefield under present conditions based on January 1941 through December 1968 records is 151,000 acre-feet. Concentrations would increase from the present 2.29 to 3.34 and 3.48 tons per acre-foot under zero and 2 tons pickup, respectively.

14. Between the Colorado River at Lees Ferry, Virgin River at Littlefield, and Colorado River below Hoover Dam

Southern Nevada Water Project, Nevada.--The Southern Nevada Water Project, now under construction, will provide supplemental municipal and industrial water to the cities of Las Vegas, North Las Vegas, Henderson, and Boulder City and to Nellis Air Force Base. It will also provide water to the potential Eldorado Valley development.

In the ultimate stage of development of the project, the estimated total annual diversions from Lake Mead by the existing Boulder City and Basic Management, Inc., water systems will be 52,000 acre-feet. The estimated total annual diversions by the project will be 328,000 acre-feet, giving a total ultimate annual diversion from Lake Mead to the project area of 380,000 acre-feet.

The estimated net annual depletion due to the project and existing systems will total 262,000 acre-feet allowing for creditable return flows of 118,000 acre-feet. The diversions in 1968 from Lake Mead were 29,790 acre-feet by Basic Management, Inc., and the Las Vegas Valley Water District, and 3,230 acre-feet for Boulder City and the Lake Mead National Recreation Area, a total of 33,000 acre-feet. No creditable return flow from these diversions was listed in the "Compilation of Records in Accordance with Article V of the Decree of the Supreme Court of the United States in the Arizona v. California Dated March 9, 1964," for calendar year 1968. If we assume for purposes of computations in this report that unidentified return flows from the 33,000 acre-feet diverted in 1968 would be in about the same proportion to diversions as was assumed in the determination of depletions for the Southern Nevada Water Project, there would be a return flow of about 10,000 acre-feet. This would give a depletion for 1968 of about 22,000 acre-feet and the additional annual depletion with full development of the Southern Nevada Water Project would be 240,000 acre-feet.

It has been assumed in this report that the Colorado River return flows from the Southern Nevada Water Project would carry as much salt as would be pumped from the river. It is possible that measures may be taken that would result in a reduction of salts returned to the river. Various proposals have been made for removing or reclaiming the return flow discharged into Las Vegas Wash in order to control pollution problems in the Las Vegas arm of Lake Mead. If any of these proposals are adopted, they will be evaluated in future progress reports.

A portion of the Southern Nevada Water Project allotment of 262,000 acre-feet will be used by the Southern California Edison Company by diverting 30,000 acre-feet annually from the Colorado River for thermal power production purposes at a site about 3 miles downstream from Davis Dam. Use of this water until July 1, 2006, by the Southern California Edison Company is in accordance with two contracts--one with the State of Nevada and the Southern California Edison Company and one with the Bureau of Reclamation and the State of Nevada. This depletion is included in the depletion anticipated for the Southern Nevada Water Project and would not cause an additional depletion.

The Southern Nevada Water Project, plus all developments above Lees Ferry and on the Virgin River, would affect the salinity at the Colorado River below Hoover Dam station. Salinity concentrations would increase from 1.03 tons per acre-foot at present to 1.29 and 1.38 tons per acre-foot for estimated future concentrations under conditions of zero and 2 tons per acre pickup.

15. Between Colorado River below Hoover Dam and Colorado River at Imperial Dam

Fort Mohave Indian Reservation.--The Fort Mohave Indian Reservation, located below Davis Dam, is allocated water by the Supreme Court Decree to irrigate 18,974 acres of land in Arizona, California, and Nevada with a maximum annual diversion from the Colorado River of 122,648 acre-feet. The consumptive use required for irrigation of these lands is estimated to be 4 acre-feet per acre, which would result in main-stream depletion of about 76,000 acre-feet annually. The Bureau of Indian Affairs reports that a major portion of this reservation is under development contract.

The consumptive use of 4 acre-feet per acre for irrigation of the Fort Mohave, Chemehuevi, and Colorado River Indian lands is based on the rate presented in Colorado River Basin Project hearings before the Subcommittee on Irrigation and Reclamation of the Committee on Interior and Insular Affairs, House of Representatives. This value is under study and may be subject to change in future reports.

Chemehuevi Indian Reservation.--The Chemehuevi Indian Reservation, located above Parker Dam, is allocated water by the Supreme Court Decree to irrigate 1,900 acres of land in California with a maximum annual diversion from the main stream of the Colorado River of 11,340 acre-feet. The consumptive use required for irrigation of these lands is estimated to be 4 acre-feet per acre, which would result in a main stream depletion of about 7,000 acre-feet annually. Full development of this reservation is expected by 1990.

Central Arizona Project.--The Colorado River Basin Project Act authorizes the Central Arizona Project for the purposes of furnishing irrigation and municipal water supplies to the water-deficient areas of Arizona and western New Mexico through direct diversion or exchange of water. This project will provide a supplemental water supply to lands now being irrigated. Water will be made available only to lands having a recent irrigation history. The Central Arizona Project must stand shortages up to its full allocation if there is insufficient main stream water to satisfy an annual consumptive use of 7,500,000 acre-feet allocated under the Supreme Court Decree of March 1964 to the States of Nevada, Arizona, and California. When shortages occur, diversions to the Central Arizona Project will be limited to assure California water users 4,400,000 acre-feet of main stream water. With present development, as reflected in the present modified flow listed in Table 18, there would be an average of 2,147,000 acre-feet available for diversion to the Central Arizona Project. With a small cutback of 25,000 acre-feet in California's historic diversion, there would be 2,172,000 acre-feet, which is all that could be diverted with a canal capacity of 3,000 c.f.s. California diversions would eventually be reduced to 4,400,000 acre-feet while the Central Arizona Project supply would gradually reduce to 433,000 acre-feet when all of the future depletions listed in Table 19 are made.

Contracts--Boulder Canyon Project.--Separate contracts have been signed with the City of Kingman, Arizona, the Lake Havasu Irrigation and Drainage District, and the Mohave Valley Irrigation and Drainage District for diversion, respectively, of 18,500 acre-feet, 14,500 acre-feet, and 51,000 acre-feet annually. Although some new lands may be developed for irrigation in the Mohave Valley Irrigation and Drainage District, other lands now irrigated will be taken out of production due to future municipal and industrial development. As a result, it is probable that the diversion under the contract with the Mohave Valley Irrigation and Drainage District would cause no appreciable increase over the present depletions from existing irrigation in the District and municipal and industrial development would result in an increased depletion of about 6,000 acre-feet per year. All of the diversions to the city of Kingman would be a depletion because of the distance of the city from the Colorado River. Diversion to Lake Havasu Irrigation and Drainage District would cause an increased depletion of about half of the diversion. It is estimated the maximum diversions allowed under the three contracts would cause an increased depletion of about 31,000 acre-feet per year.

ANTICIPATED EFFECTS OF ADDITIONAL DEVELOPMENTS

Lower Colorado River Indian Reservation.--The Lower Colorado River Indian Reservation is located along the Colorado River just below Parker Dam, Arizona, with most of the land in Arizona and the remainder in California. The Supreme Court Decree allocated 717,148 acre-feet of diversions to the Colorado River Indian Reservation for irrigation of 107,588 acres of land. The consumptive use required for irrigation of these lands is estimated to be 4 acre-feet per acre, which would result in an annual main stream depletion of 430,352 acre-feet. The consumptive use in 1968 from irrigation of 46,748 acres is estimated to be 186,992 acre-feet. This leaves an additional depletion of about 243,000 acre-feet per year for future developments.

Lower Colorado River Channelization Project, Arizona-California.--Between Davis Dam and Parker Dam, the channelization work in the Mohave Valley Division was completed in 1960 to salvage an estimated 109,000 acre-feet of water per year. However, the permanence of 44,000 acre-feet of that salvage is dependent on future maintenance in the Topock Gorge Division. The work in the Topock Gorge Division would also salvage an additional 28,000 acre-feet per year.

Between Parker Dam and Imperial Dam, work in the Palo Verde Division to salvage 10,000 acre-feet of water per year has been completed and is considered to be reflected in the 1968 streamflow records. Work in the Cibola Division to salvage 36,000 acre-feet per year was completed in 1970 but is not considered to be reflected in the 1968 streamflow records. Work in the Parker and Imperial Divisions to salvage 39,000 acre-feet per year has not yet been started.

In summary, at the end of 1968 channelization work to salvage 119,000 acre-feet of water per year was complete, and work to salvage 103,000 acre-feet per year was either underway or planned.

It is estimated that an additional 100,000 acre-feet of water per year could be salvaged by phreatophyte eradication and control. The locations where work would be done have not been finally selected. For purposes of this study, locations of salvage developed for the Pacific Southwest Water Plan have been used. It indicated salvage of 88,000 acre-feet would be above Imperial Dam; of this amount, 59,000 acre-feet would be above Parker Dam and 29,000 acre-feet would be between Parker and Imperial Dams. The combined annual salvage above Parker Dam from the channelization and phreatophyte eradication and control programs would be 87,000 acre-feet. Between Parker and Imperial Dams, the salvage from the combined programs would be 104,000 acre-feet. The total salvage above Imperial Dam is 191,000 acre-feet.

In addition to developments above Hoover Dam, the Central Arizona Project, development of Indian lands on the Fort Mohave, Chemehuevi, and Colorado River Indian Reservations, a decrease in diversions through the

Colorado River Aqueduct by the Metropolitan Water District, separate contracts to various water users, and increases to the water supply resulting from salvage by channelization and phreatophyte control of the Lower Colorado River will all contribute to changes in the salinity concentration at Imperial Dam.

Salinity concentrations at the Colorado River below Parker Dam station would increase from the present 1.01 tons per acre-foot to 1.27 and 1.37 tons per acre-foot for the zero and 2 tons per acre pickup conditions, while the concentration at Imperial Dam would increase from the present 1.18 tons per acre-foot to 1.57 and 1.70 tons per acre-foot for the zero and 2 tons per irrigated acre pickup conditions.

PART VII. EFFECTS OF SALINITY ON WATER USE

Water quality can be a limiting factor in the use of a water supply. Different water uses require different water qualities, and a supply may thus be acceptable for some uses but unsuitable for others. Most water uses have a range of quality within which a supply may be acceptable for that use. Use of water at the low quality end of this range may impose an economic, a social, and/or a political penalty on the water user in comparison to use of the water at a higher quality. The suitability of the quality of a water supply for use is thus a relative matter and must be evaluated with regard to specific uses and the social and economic aspects of such use.

A major objective of this report is to assess the suitability of Colorado River water for various beneficial uses. The following sections discuss the physical and economic effects of salinity on water uses in the Colorado River Basin. The effects of water quality on water uses as measured by parameters other than salinity are discussed in Part IX.

A. In-stream Use

The major in-stream uses of water in the Colorado River Basin include hydroelectric power production, propagation of fish and aquatic life, recreation (including water contact sports), and aesthetics. Within the range of salinity concentrations expected in the foreseeable future, salinity should have no significant effects on these uses.

B. Irrigation Use

A major portion of the basin water supply is consumptively used for irrigation. Any effects of water quality on this use are thus of major importance. Crops grown in the basin differ in sensitivity to a salt concentration in the soil root zone, with some crops tolerating significantly higher concentrations in the root zone than the more sensitive crops. Also, most crops require a lower salinity concentration in the root zone during the germinating and seedling stage than they do later in the growing cycle. Salinity concentrations in the root zone are affected by the salinity concentration of the irrigation water, the relationship of consumptive use to the water supplied to the crop by irrigation and rainfall, and the drainability of the soil. If, however, all other factors remain unchanged, the salinity concentration of the root zone will vary with the salinity concentration of the irrigation water. Thus an increase in the salinity concentration of the irrigation water will decrease the productivity of the crops if its tolerance limit of salinity concentration in the root zone is exceeded. Because of the many factors affecting the salinity concentration in the root zone, an exact irrigation water concentration that will damage a crop cannot be determined.

Damage to crops can be prevented by applying additional irrigation water to flush the salts from the soil. If natural drainage or an existing drainage system is inadequate to remove the additional water, it may be necessary to install additional drains. Without sufficient water for flushing the salts from the soils the grower has the choice of producing less per acre or of switching to a crop that is more salt tolerant. The more salt-tolerant crops, however, generally have a lower economic return than the salt-sensitive crops. Therefore, it is probable that, if the salinity concentration of the irrigation water becomes high enough to cause damage to crops, the grower will suffer a decrease in his economic return.

In the Upper Basin, salinity concentrations during the irrigation season are relatively low except in local areas. The impact of salinity on irrigation in the Upper Basin is thus minimal.

In the Lower Basin, present peak salinity concentrations are approaching critical levels for some salt-sensitive crops and, while suitable for irrigation of most crops, are believed to be high enough that in some cases decreases in crop yields could occur. Although Colorado River water is accepted for irrigation use, future increases in salinity may thus involve the incurring of a small but significant economic loss.

C. Industrial Use

Colorado River water has not been widely used for industrial purposes within the basin, but extensive use has been made of this water from transmountain diversions outside the basin. Since the quality of the water diverted from the Upper Basin is relatively high, only minimal pretreatment is required for most industrial uses. In the Lower Basin, the higher salinity levels in the diverted flows may require more extensive pretreatment for some types of industrial uses.

The quality of water required for industrial use varies widely and is dependent upon the purposes for which the water is utilized. Within any industrial plant, water may have several functions.

Cooling is the largest single use of industrial water supplied from the Colorado River, ranging from 57 percent to 80 percent. Because available water is limited, recirculatory cooling systems are the prevalent type. About 3,000 mg./l. is the maximum salinity concentration that can be used in a system unless it is constructed of corrosion-resistant material. Salt concentrations are held below this limit by blowdown (discharging a part of the cooling water to waste and replacing it with water having a lower salinity concentration). Usually the cooling water and boiler system water are treated to inhibit scale formation and corrosion. The amount of cooling water needed by a specific industry is proportional to the salinity concentration of the available water. The cost of treating both cooling and boiler water also varies proportionally with the salinity concentration.

Tables 20-25, showing yearly summaries of the ionic loads at six stations, can be used by industry to evaluate the water available to meet its needs.

D. Domestic Use

For domestic water use, it is desirable to have a safe, clear, potable, aesthetically pleasing water supply which meets the recommended limits of the Public Health Service Drinking Water Standards of 1962. High salinity levels affect the taste of drinking water and may affect the digestive system in some people. Water hardness, which generally increases with increases in salinity concentrations, also requires more soap and laundry additives to achieve acceptable cleaning results. If the water becomes too hard, softening of the supply in large-scale municipal plants or in individual home units may be required. Sealing of water heaters and corrosion of pipes also accelerate with increased salinity or hardness levels.

Water quality in the Upper Basin will generally meet the Public Health Service standards with normal levels of treatment--settling, filtration, and disinfection. In some cases only disinfection is required. In contrast to the Upper Basin, the water supply at most points in the Lower Basin does not meet the Public Health Service recommended limits for total dissolved solids, exceeding the maximum acceptable limits at times. Mineralized water supplies with salinity concentrations in the range of those values observed in the Colorado River, however, are commonly accepted in the southwestern United States, with little detriment to the potability of the supply. The use of this mineralized supply imposes an increased treatment cost as hardness levels are high enough that water softening is provided for some of the supply in addition to normal treatment.

Softening of Colorado River water is extensive enough that small increases in hardness affect softening costs appreciably.

PART VIII. THE POTENTIAL FOR SALINITY CONTROL

The various legislative acts discussed in Part I authorize the Secretary of the Interior to study means of improving the quality of water in the Colorado River Basin and to develop comprehensive plans for achieving such water quality enhancement. A number of activities have been undertaken with the objectives of evaluating various salinity control aspects. Some of these activities were previously discussed. The following sections summarize the present knowledge of the potential for achieving basinwide control of salinity.

A. Technical Possibilities for Salinity Control

There are a number of salinity control measures which could be potentially useful for minimizing and controlling salinity in the Colorado River Basin. These measures, which may be divided into measures for increasing the water supply and measures for reducing the salt load, are listed in Table D .

Various factors such as economic feasibility, lack of research, and legal and institutional constraints limit the practicality of most measures. The most practical means of augmenting the basin water supply include importing water from other basins, importing demineralized sea water, and utilizing weather modification techniques to increase precipitation and runoff within the basin. Practical means of reducing salt loads include: impoundment and evaporation of point source discharges, diversion of runoff and streams around areas of salt pickup, improvement of irrigation and drainage practices and facilities, desalination of saline discharges from natural and man-made sources, and desalination of water supplies at points of use.

B. Feasibility of Salinity Control

Eight potential alternative salinity control programs incorporating a variety of control measures were formulated by the Federal Water Quality Administration to provide the basis for evaluating the costs and salinity control effects of a basinwide control program. These alternatives included three salt-load reduction programs, four flow augmentation programs, and one program to demineralize water supplies at the point of use.

The three salt-load reduction programs utilized control measures such as desalination or impoundment and evaporation of mineral spring discharges, irrigation return flows and saline tributary flows, diversions of streams and improvement of irrigation practices and facilities. The Federal Water Quality Administration estimated that the programs have a potential salt-load reduction of up to 3 million tons annually and possibly could reduce average salinity concentrations at Hoover Dam by about 200 to 300 mg./l.

Table D . Possibilities for Salinity Control

I. Measures for increasing water supply

  A. Water conservation measures
    1. Increased watershed runoff
    2. Phreatophyte control
    3. Optimized water utilization for irrigation
      a. Reduced consumptive use
      b. Improved irrigation efficiency

  B. Water augmentation measures
    1. Weather modification
    2. Water importation
      a. Fresh water sources
      b. Demineralized sea water

II. Measures for reducing salt loading

  A. Control of natural sources
    1. Natural discrete sources
      a. Evaporation of high saline discharges
      b. Injection into deep geological formations
      c. Desalination
      d. Suppression of discharge
      e. Reduction of recharge
    2. Natural diffuse sources
      a. Surface diversions
      b. Reduced ground water recharge
      c. Reduced sediment production

  B. Control of man-made sources
    1. Municipal and industrial sources
      a. Evaporation of high saline discharges
      b. Injection into deep geological formations
      c. Desalination
    2. Irrigation return flows
      a. Proper land selection
      b. Canal lining
      c. Improved irrigation efficiency
      d. Proper drainage
      e. Treatment or disposal of return flows

The four flow augmentation programs evaluated were based on three potential sources of water: increased precipitation and runoff through weather modification, interbasin transfer of water, and importation of demineralized sea water. Since investigations of the potential feasibility of interbasin transfer of water into the Colorado River Basin are prohibited by law until after 1978, the evaluation of such programs was limited to the effects of flow augmentation on salinity concentrations and did not include an evaluation of the feasibility of interbasin transfer or of potential sources of surplus water. The volume of flow augmentation assumed to be provided by the programs evaluated ranged from 1.7 to 5.9 million acre-feet annually. Resulting reductions in average salinity concentrations at Hoover Dam ranged from 100 to 300 mg./l.

Desalination of water supplies diverted from the Lower Colorado River for use in Southern California was evaluated as an alternative to reducing salinity levels in the river system.

C. Salinity Control Investigations

Both the Bureau of Reclamation and the FWQA have participated in a number of basic studies directed toward the objectives of developing and demonstrating methods of minimizing salinity concentrations in the Colorado River system. In addition to the research efforts previously discussed in Section E, Part IV, several salinity control investigations have just been completed or are in progress. These investigations are discussed below.

1. Cooperative Salinity Control Reconnaissance Study

Early in FY 1968, the FWQA and the Bureau of Reclamation initiated a cooperative salinity control reconnaissance study in the Upper Basin to identify controllable sources of salinity, determine technically feasible control measures, and estimate their costs. The first year of this study was financed by a transfer of funds from FWQA to the Bureau, and the second year was financed by the Bureau. A shortage of funds forced discontinuance of the study during FY 1970. The results of the study to date will be presented in a report to be released at a later date.

Reconnaissance level preliminary plans were developed by the study for two salinity control projects and cost estimates prepared for a number of control methods. One preliminary plan developed was for the Paradox Salinity Control Project which would reduce the heavy pickup of salt by the Dolores River as it crosses a salt anticline in Paradox Valley in western Colorado. Control would be achieved by regulating peak flood flows and conveying the streamflow through a lined canal past a recharge area for a saline ground water system. Estimates of project costs and salinity control benefits were prepared which indicated this project may be economically feasible.

A preliminary plan was also prepared for a project to control the salt load from Crystal Geyser, an abandoned oil test well which periodically discharges highly mineralized water in much the same manner as a geyser. Control would be achieved by collecting the geyser discharge and pumping it to a lined impoundment for evaporation. Cost estimates for this project also indicated marginal economic feasibility. A project of this type may be potentially applicable to control of some of the more concentrated small mineral springs if suitable land area for an evaporation pond can be found and evaporation rates are high enough.

For control of irrigation return flows, the costs of impounding and evaporating the flows at two topographically different sites were estimated. The costs of deep well injection of relatively small quantities of the more concentrated return flows were also estimated. The feasibility of controlling irrigation return flows by evaporation or deep well injection would appear to be doubtful at this time on the basis of salinity control benefits alone.

The cost of lining canals and distribution systems in several existing irrigation projects as a salinity control measure was also investigated. The economic feasibility of this type of control measure was not evaluated, however, as the effectiveness of canal lining in reducing salt loads from irrigated areas has not been fully determined.

2. Grand Valley Salinity Control Demonstration Project

This project, located near Grand Junction, Colo., was initiated in FY 1969 under a FWQA demonstration grant. The objective of this project is to demonstrate the salinity control potential of lining irrigation canals and laterals. The Grand Valley is underlain by an aquifer containing highly saline ground water. Seepage from canals and laterals contributes to the recharge of this aquifer. This recharge displaces the saline ground water into the Colorado River, increasing its salt load. Reduction of such recharge by reducing seepage from conveyance systems is thus expected to reduce the salt load discharged to the river.

A major portion of the canals and some of the laterals serving a study area of about 4,600 acres were lined with concrete in 1969 and 1970. Most of the lining was accomplished by a corporation of local irrigation and drainage districts which direct the demonstration project. Colorado State University is conducting the data collection activities and evaluating the salinity control effects under contract from the corporation. A simulation model is being developed which will evaluate the effects of changes in irrigation efficiency on salt-load contributions as well as changes in seepage losses from the conveyance system. This model will allow the results of the demonstration project to be projected valley-wide upon completion of the study and form the basis for future salinity control activities in this location. Completion of the demonstration project, including all post-construction studies, is scheduled for mid-1972.

3. Other Related Investigations

A research project entitled, "Effect of Water Management on Quality of Ground Water and Surface Recharge in Las Vegas Valley," was initiated by Desert Research Institute in late 1969 under a FWQA research grant. This project will evaluate, among other things, the movement of salts in the ground water system and the exchange of salts between the ground water and surface waters of Las Vegas Wash. Research results will help define the optimum approach to control of this salt source. Completion of the research effort is scheduled for mid-1973.

A cooperative regional research effort, "Project W-107, Management of Salt Load in Irrigation Agriculture," was initiated in 1969 by seven western universities and the Agricultural Research Service's U.S. Salinity Laboratory. Work underway or planned covers a wide range of salinity management aspects and should provide data applicable to basin salinity problems.

D. Completed Salinity Control Projects

During the latter part of FY 1968, the FWQA made funds available and requested the Bureau of Reclamation to select a pilot project to test and demonstrate control methods for reducing salinity concentrations and salt loads in the Colorado River system. The plugging of two flowing wells, the Meeker and Piceance Creek wells near Meeker, Colo., was selected as the pilot demonstration project. The Bureau of Reclamation's contractor completed plugging the Meeker well on August 3, 1967, and the Piceance Creek well on August 9, 1968. Closing of the Meeker well reduced the sodium and chloride concentrations of the White River by over 50 and 75 percent, respectively, at the Geological Survey gage below Meeker. Plugging the Piceance Creek well decreased the sodium, bicarbonate, and chloride concentrations over 10 percent at the mouth of Piceance Creek, 13 miles downstream from the well. The salinity load of the White River and the Colorado River system was reduced by about 62,500 tons annually. This is about 19 percent of the average annual salinity load in the White River near Watson, Utah. Plugging the Meeker and Piceance Creek wells initially decreased the annual flow of the White River by about 2,380 acre-feet. It is the opinion of the Bureau's regional geologist that the flow formerly discharged from the wells will reappear through natural springs nearer the recharge area at an improved quality, and that plugging the wells will not cause a permanent decrease of the annual flow in the White River.

Costs for plugging the two wells totaled $40,000. It is estimated by the Federal Water Quality Administration that the present worth of total benefits which will accrue to Colorado River water users is approximately $7 million. Thus, this project demonstrated the economic feasibility of plugging similar flowing saline wells in addition to demonstrating significant local water quality improvement. The high benefit-cost ratio for this project would indicate that plugging wells discharging considerably lesser amounts of salt would be economically feasible.

Another flowing well near Rock Springs, Wyo., which contributed approximately 5,000 tons of salt annually, was plugged in November 1968 under the direction of the Wyoming State Engineer. The effects of eliminating this salt source have not been evaluated.

In late 1969 the Utah Oil and Gas Commission plugged seven abandoned oil test wells near Moab, Utah. This action eliminated a salt load of approximately 33,000 tons per year which was formerly contributed by two of the wells. The other five wells were not flowing. Costs of plugging the wells totaled about $35,000.

It is estimated that plugging the five flowing wells in Colorado, Wyoming, and Utah will reduce the average annual salt load passing Hoover Dam by 100,000 tons or 0.93 percent. This salt load reduction would reduce average salinity concentrations by about 6 mg./l. under present conditions. Although this change in salinity concentrations is small with respect to present salinity levels, the resulting economic benefits are significant. These annual benefits are estimated to range from $400,000 in 1970 to $1 million in the year 2010 and have a present worth of more than $10 million. Thus, a modest but significant start has been made toward reducing the economic impact of rising salinity concentrations.

PART IX. OTHER WATER QUALITY ASPECTS

Although salinity is considered to be the most serious water quality problem in the Colorado River Basin, there are a number of other water quality problems of varying degrees of significance which warrant discussion. The following sections discuss the most significant sources of water quality degradation and the effects of such degradations on water uses as measured by various parameters.

A. Source of Water Quality Degradation

1. Municipal Wastes

Municipal wastes are described herein as those liquid-carried wastes of domestic and service industry origin. Within the Colorado River Basin the majority of the discharges from waste water treatment plants enter the river system and are the primary sources of bacteriological and organic pollution. Most of the municipal waste sources in the basin receive secondary treatment plus disinfection which is the minimum degree of treatment required by the Basin States.

Compliance schedules have been established for municipalities whose waste discharges are not meeting the water quality standards set by the States. At the present time, pollution from municipal waste sources is confined to those reaches of stream immediately downstream of the waste effluent, and measures are being taken or have been planned for the control or abatement of pollution from these sources.

2. Industrial Wastes

Industrial wastes are defined as those spent process waters, cooling waters, wash waters, and other waste waters associated with industrial operations. The pollutants derived from industrial wastes other than salinity are toxic materials, oils and grease, floating materials, radioactivity, oxygen-demanding substances, heat, color-, taste-, and odor-producing substances, and bacteria.

The pollution problems associated with the discharge of industrial wastes in the Colorado River system have been generally confined to local reaches of stream. An exception occurs, however, with the discharge of uranium mill effluents because of the persistent nature of the radioactivity in these effluents. Two enforcement conferences were called by the FWQA (formerly the Public Health Service, Division of Water Supply and Pollution Control) in the Animas River and the Colorado River Basins in an attempt to find solutions to the problems associated with uranium mill discharges. The majority of the uranium mills in the Colorado River

Basin have been closed but there still exists the potential for water pollution from the remaining mill tailings piles.

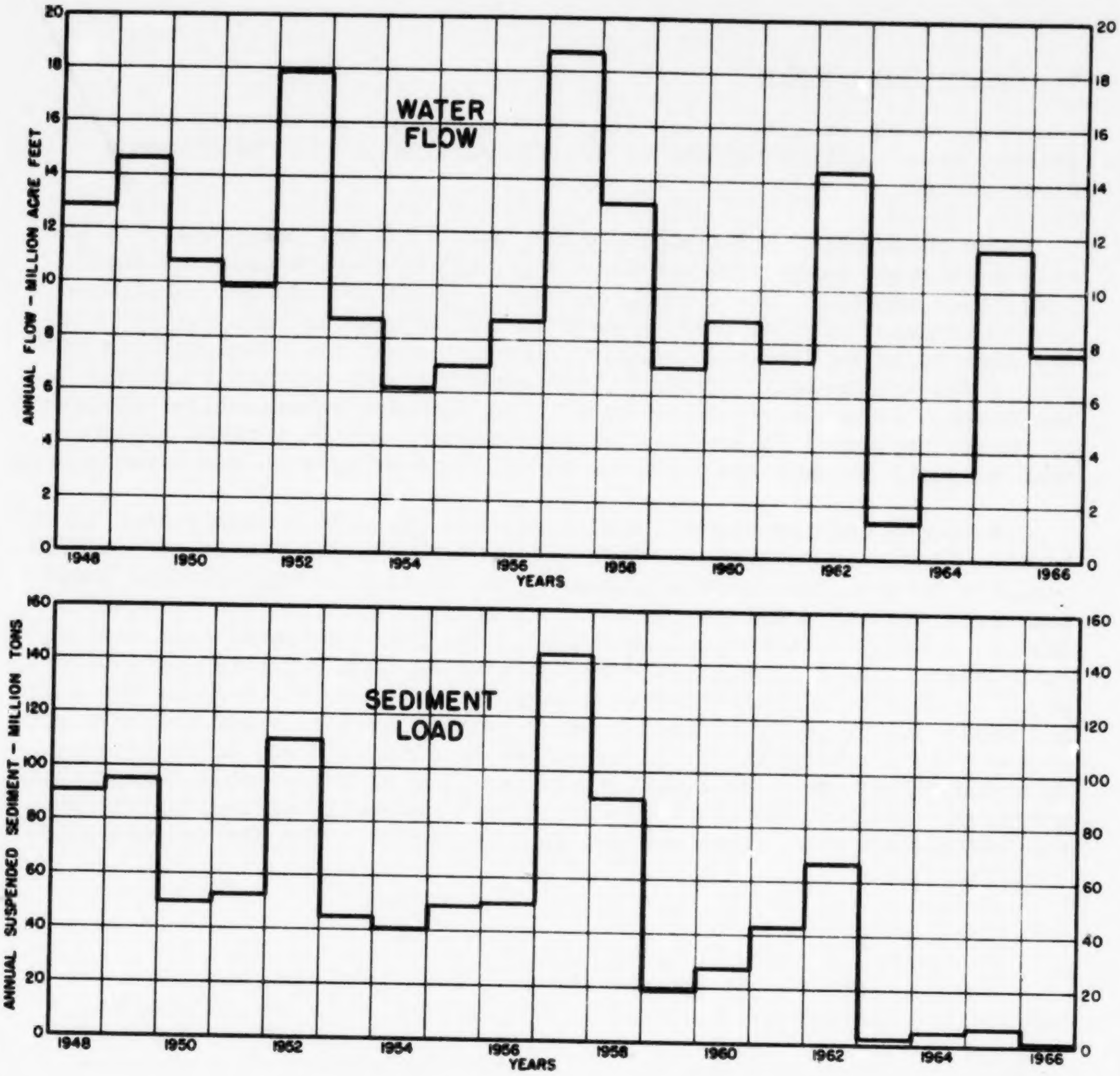
With the establishment of Water Quality Standards on interstate streams and compliance schedules for the implementation of these standards, the pollution from industrial waste sources in the basin has been or is being abated or controlled.

3. Sediment

Prior to construction of the storage units of the Colorado River Storage Project, most of the larger tributaries and the main stem of the Colorado River carried large loads of sediment, particularly in their middle and lower reaches.

For example, in 1957 the suspended sediment load of the Colorado River at Lees Ferry, Ariz., gaging station was recorded at 143 million tons. This sediment was detrimental to water diverters for consumptive use as well as to high-type fishery and other recreational uses. The construction of Fontenelle, Flaming Gorge, Curecanti Unit, Navajo, and Glen Canyon Dams has produced dramatic changes in the sediment load transported by these streams. For example, the relationship between the water and sediment flows at Lees Ferry during the 1948-66 period is illustrated in Figure 9 . In 1959 the cofferdam utilized in the construction of Glen Canyon Dam was finished and diversions began through the tunnels. Sediment was deposited behind the cofferdam in 1959 and 1960 at a sufficient rate to gradually fill the cofferdam lake with the result that by 1962 the annual sediment load at Lees Ferry had increased to 67 million tons. This load dropped to 2.2 million tons in calendar year 1963 with the closure of Glen Canyon Dam and initial storage in Lake Powell. Lake Powell and other Colorado River Storage Project reservoirs are now effectively trapping and storing almost all of the sediment originating in the Upper Colorado River Basin. Lake Powell traps approximately 80 percent of the sediment that normally would flow into Lake Mead. By storing the sediment in the Colorado River Storage Project reservoirs, the streams immediately below the dam have been changed to relatively clear trout water fisheries as well as desirable boating and recreational areas.

Suspended sediment records have been maintained at key locations to measure the changes taking place. Some of these stations are shown in Tables 39 to 44 and include Green River near Jensen, Utah; Green River at Green River, Utah; Colorado River near Cisco, Utah; San Juan River near Bluff, Utah; Colorado River at Lees Ferry, Ariz., and Colorado River near Grand Canyon, Ariz. Because the sediment load was essentially eliminated by the Glen Canyon Dam, sediment measurements at Lees Ferry were discontinued in September 1966.



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO RIVER
AT LEES FERRY
SEDIMENT & WATER FLOW

Fig. 9

4. Agricultural Wastes

Neglecting salinity pollution, pesticides, and fertilizers are the primary water pollutants associated with agriculture in the Colorado River Basin.

The chlorinated hydrocarbon group, e.g., DDT and Toxaphene, are the most persistent pesticides and are of primary concern because of their long-range impact. The organic phosphate compounds do not persist in the environment for the period the chlorinated hydrocarbons do, but they are more toxic to fish and humans. Data have been collected showing that pesticides are present in sufficient quantities at certain locations in the Lower Colorado River to be harmful to fish and aquatic life. The use of these compounds in areas above public water supply intakes requires that adequate precautions be taken to preclude entry into the river system.

Nitrogen and phosphorus fertilizers are the most commonly used in the basin. Studies conducted in other areas of the United States show a relationship between the concentrations of nutrients from agricultural lands and water quality problems caused by excessive fertilization of aquatic plants. The 1966 water quality study by the FWQA indicated that significant quantities of phosphorus were contributed from irrigated agriculture along the Lower Colorado River. Within the Colorado River Basin the animal waste pollution is minimal because outside surface water has been prevented from entering the feedlots either by directing the drainage away from the operation or by locating the facility in a favorable topographic position. Feedlot wastes, moreover, do not generally accumulate within the basin since facilities are set up to distribute the wastes onto adjacent farmland.

5. Mine Drainage

During 1966 to 1968 approximately 75 locations were sampled to determine the heavy-metal concentrations contributed by mine drainages, tailing piles, and natural sources within the Colorado River Basin. The streams with degraded reaches are listed in Table E which also shows the major sources and effects of the pollution. Many of these streams have heavy-metal concentrations in excess of PHS Drinking Water Standards and destroy aquatic life in about 120 miles of stream channel.

The Federal Water Pollution Control Act, as amended, authorizes the Secretary of the Interior to enter into agreements with any state or interstate agency "to demonstrate methods for the elimination or control, within all or part of a watershed, of acid or other mine water pollution resulting from active or abandoned mines." Efforts are currently underway to initiate an agreement under the provisions of this act to evaluate the effectiveness of several mine drainage control methods in the southwestern portion of the State of Colorado.

OTHER WATER QUALITY ASPECTS

Table E. Mine Drainage Sources and Effects, Colorado River Basin

Stream	Area of investigation	Major sources	Effects
Blue River			
Tenmile Creek	Headwaters to mouth at Frisco, Colo.	Wilfrey Mine; pump failure at Amax tailings ponds.	Some areas devoid of aquatic life due to high heavy-metals concentrations
Eagle River	Homestake Creek near Redcliff to Minturn, Colo.	Mineral spring near Belden, Colo.; former seepage from old tailings pile; New Jersey Zinc Corp. decant.	Aesthetics; destruction of biological productivity; high heavy-metals concentration; predominantly zinc.
Gunnison River			
Lake Fork	Headwaters to Lake City, Colo.	Golden Fleece Mine.	Aesthetics in northwest portion of Lake San Cristobal.
Uncompahgre River	Headwaters through Dexter Creek, upstream of Ouray, Colo.	Red Mountain Creek; via Genessee, Rouville, and Joker Tunnels, and Red Mountain adit; natural sources.	Aesthetics; low pH; high heavy-metals and mineral concentration; devoid of aquatic life.
Dolores River	Mouth of Coal Creek to Dolores-Montezuma County line.	St. Louis and Blaine Tunnels; Silver Swan adit; and others.	Aesthetics; minimal effect due to neutralization of mine drainage by natural river alkalinity.
San Miguel River	Upstream of confluence with South Fork.	Iron Springs; Penn Tunnel; other mine drains; natural sources.	Aesthetics; high heavy-metals concentration; minor effects on biological productivity.
San Juan River			
Animas River	Headwaters through Mineral Creek south of Silverton, Colo.	Cement Creek, north Mineral Creek via Bagley, American, and Koehler Tunnel; other adits, mills, and mine drains, natural sources.	Aesthetics; high heavy-metals concentration, particularly zinc; many areas devoid of aquatic organisms.
La Plata River	Headwater to Hesperus, Colo.	Natural sources.	Minimal effects.
Mancos River	Headwaters to confluence of Middle and East Forks.	Natural mineral seep.	Some destruction of aquatic life, particularly fish.

B. Water Quality Parameters Other Than Salinity and Sediment

1. Dissolved Oxygen

The dissolved-oxygen concentration is a measure of the water capacity to support life and assimilate organic wastes. The records show that the dissolved-oxygen concentrations in the Colorado River Basin are generally above established standards. However, a marked reduction in the concentration can be found during the summer months below some municipal and industrial discharges and in some streams with very low flows. A 1966 investigation indicated that there might be a wide diurnal variation in the oxygen concentrations in some reaches because of the large amount of algae in the streams with oxygen saturation being reached during a sunlit day and a minimal concentration occurring at night when oxygen is used by the plants.

2. Temperature

The Colorado River Basin water temperatures vary widely, reaching the highest levels during the summer months when they vary from near freezing in the high mountains to above 90° F. in the lower reaches. Warmer temperatures may increase the rate of growth and the decomposition of organic matter and of chemical reaction, resulting in bad odors and tastes, and also decrease the dissolved oxygen concentration available to sustain a fishery.

Changes in water temperature in the basin result primarily from natural climatic conditions. The large reservoirs, however, may affect the stream temperatures for a considerable distance below the reservoir. Temperature records indicate that Flaming Gorge Reservoir has little or no effect on winter temperatures but cools the summer temperatures of the Green River up to 5° F. at the Green River, Utah, station. Navajo reservoir appears to have no effect on the temperatures of the San Juan River at the near Bluff station. Lake Powell appears to warm the winter temperatures of the Colorado River at the Grand Canyon station by up to 10° F. and cool the summer temperatures by about the same amount.

Thermal springs, waste-water discharges, and irrigation return flows may increase the temperatures in the receiving water, but the added heat is usually dissipated in a relatively short distance from the source. Flow depletions and changes in stream channel characteristics may also increase the effects of natural climatic conditions causing cooler or warmer water temperatures.

Temperature increases due to municipal and industrial waste discharges have been minimal; however, the construction of thermal powerplants in the basin with a return of the cooling water to the streams or reservoirs presents a potential for temperature increases. Any thermal discharge coupled with flow depletion could have a significant effect on water temperatures.

Tables 26 through 38 contain the temperature records of 13 stations.

3. pH

The pH of the waters in the Colorado River Basin usually range from about 7 to 8 pH units with the exception of those streams receiving acid mine drainage. In this latter case the pH is lowered to levels which preclude the establishment of aquatic life and the use of the river for a fishery and other purposes.

4. Heavy Metals

Various heavy metals such as copper, lead, zinc, iron, manganese, arsenic, and cyanide are found in the waters of the basin. These vary from trace amounts to potentially hazardous levels. The presence of these heavy metals is generally contributed by drainage from active and inactive mining operations.

Iron and manganese concentrations frequently exceed the Public Health Drinking Water Standards in many basin streams. This is particularly evident in the upper reaches of the Colorado and San Juan Rivers and their tributaries. A 1966 water quality survey showed that heavy metal concentrations have a marked effect on the aquatic life. Toxicity of these metals to aquatic life is dependent not only on the toxicity of a single metal but also the synergistic effects of two or more metals. Certain reaches of stream are completely devoid of bottom organisms and fish because of these toxic effects.

5. Toxic Materials

In addition to the toxic effects of heavy metal concentrations, toxic materials are also contributed to the stream through industrial and agricultural operations. Limited long-term monitoring at four surveillance stations located on the Colorado River has detected the pesticides DDD, DDE, DDT, dieldrin, and endrin. There are, however, no data available for pesticides in other streams of the basin. A comprehensive evaluation of the effects of pesticides upon water quality cannot be made at this time because of the lack of water quality data and incomplete knowledge of the physiological and other effects of pesticides in human, wildlife, fish, and other biological forms. The mere presence of a pesticide in water does not necessarily indicate serious pollution. In recent years, however, several fish and bird mortalities, attributed to residual pesticides, have occurred downstream of and in irrigation drains along the Lower Colorado River.

6. Nutrients

Nutrients, primarily nitrogen and phosphorus, are believed to be the most conducive to the growth of algae. The sources of these nutrients are runoff from agricultural lands, municipal and industrial waste waters, and natural runoff. Phosphorus is normally found in only limited quantities in unpolluted water. Sufficient nitrogen is generally available naturally in basin waters to stimulate algae growth.

Quiescent reservoir waters are more susceptible to excessive plant growths than are rapidly flowing streams. Excessive growth of aquatic plants are present in the Las Vegas Bay (a highly used recreational area on Lake Mead) as a result of large nutrient inputs derived primarily from municipal and industrial effluents from the metropolitan Las Vegas area. The extensive algae growth has affected the use of the lake as a public water supply.

The nutrient concentrations in other lakes in the basin have reached levels which can support excessive algae growths. An excessive algae growth has been cited as the probable reason for a fish kill which occurred in the Flaming Gorge Reservoir in late 1963.

In the lower reaches of the Colorado River excessive aquatic plant growths have been associated with fertilization by nutrients discharged to irrigation return canals. A small increase in the nutrient levels in the river has been attributed to heavy recreational activities along the river below Davis Dam.

7. Bacteria

The coliform group of bacteria is used as an indicator of pollution. This group is made up of bacteria of diverse origin including that found in the intestinal tract of humans and other warmblooded animals as well as in the soil and on vegetation. High coliform counts in waters indicate the probable presence of pathogenic organisms where bacterial contamination from sewage or animal wastes appears likely.

In recent years analytical procedures have been developed whereby coliform bacteria of fecal origin can be identified. Fecal coliform tests measure bacteria from both man and animal. All the states of the basin have set standards for fecal coliform as the bacterial indicator of pollution.

High bacterial counts were observed at many locations in the Colorado River Basin during the 1966 water quality study. A number of these resulted from raw sewage discharges into a stream. In some cases, however, it was because of poor disinfection of the municipal waste water treatment plant effluents. The raw sewage discharges which were observed during the 1966 survey have been or are scheduled to be corrected by the addition of ponding treatment.

Bacteriological pollution has also been observed in popular recreation areas. For example, the fecal coliform densities in Lake Mead have been observed at densities higher than the standards set for body contact recreation (100/100 ml.).

Bacteriological pollution has an effect on most of the uses cited earlier. In those cases where it exceeds the criteria set for body contact recreation, it results in the closure of swimming areas. With high coliform counts, the use of water as a public water supply is impaired.

8. Radioactivity

An assessment of the radioactivity in the basin waters should also consider strontium 90 (Sr-90) radionuclides associated with atmospheric fallout in addition to radionuclides associated with industrial activities. Strontium 90, like the radionuclide Ra-226, is damaging to human bone cells. The effects of Ra-226 and Sr-90 are additive.

Radioactive pollution from industrial waste water effluents, i.e., uranium mills, was, prior to 1960, the major source of radioactive pollution in the basin. The majority of the mills have been closed down but a significant portion of the increase of radioactivity originates from the abandoned tailings piles. In combination with other radionuclides (e.g., Sr-90) the waters of the Colorado River system are now approaching or exceeding the recommended limits for radioactivity.

Radioactivity does impair the water for beneficial use when concentrations exceed certain limits. For example, the Public Health Drinking Water Standards set a mandatory limit of 3.0 picocuries Ra-226 and 10 picocuries/liter Sr-90. Moreover, the combination of these two radionuclides should conform to the following relationship: $\frac{\text{Sr-90}}{10} + \frac{\text{Ra-226}}{3} \leq 1.0$.

PART X. CONCLUSIONS

These studies indicate an overall increase in the concentration of total dissolved solids at the various points on the Colorado River and its tributaries under the conditions described. The quality of water will still be acceptable for present and most projected uses although some quality control measures are desirable in order to keep the future concentrations within usable limits.

Salinity is introduced into the Colorado River system from various sources but the natural source contributes the major portion of total dissolved solids. The addition of large storage units throughout the entire basin has dampened out the longtime and annual fluctuations in water quality.

The dampening influence on water quality fluctuations by many reservoirs in the basin will make it possible to more accurately forecast the quality of water delivery to the many projects and points of diversion in the basin.

The tributaries with exceptionally high dissolved-solids content have minor effect on the dissolved-solids concentration of the Colorado River as the volume of water and total tonnage of dissolved material represent only a very small portion of the total.

The special studies of irrigation projects that have been undertaken and their effect on the chemical quality of water permit these preliminary conclusions:

1. The early years of irrigation are generally the most detrimental to downstream water quality. This is primarily due to an abundance of soluble salts not previously exposed to a large amount of water.

2. Firm determinations cannot be made during the early years of development regarding the ultimate effect of irrigation. The primary factors in establishing equilibrium are the availability of soluble salts in the soils, the capacity of the ground water reservoirs, and the uniformity of irrigation practice in the area in question.

3. Each irrigated area has a different effect on quality depending upon properties of the soils and substrata in the drainage area, number of years the land has been irrigated, number of times return flow is reused, nature of the aquifers, rainfall, amount of dilution caused by surface wastes, temperature, storage reservoirs, vegetation, and types of return flow channels.

CONCLUSIONS

4. Future studies should consider other aspects of water quality effects, such as ion exchange, selective precipitation of salts, and changes in chemical composition (hardness, concentrations of specific constituents, etc.) on the river systems.

Programs to alleviate salt contributions to the river system are now underway in local areas.

Pollution to the Colorado River Basin other than salinity have not been a major problem in the past and with careful surveillance and control measures may not become a major problem in the future.

References Cited

Iorns, W. V., Hembree, C. H., and Oakland, G. L., 1965, Water Resources of the Upper Colorado River Basin--Technical Report: U.S. Geological Survey Professional Paper 441, 370 pages.

Table I
Colorado River Basin
Historical Flow and Quality of Water Data
Green River near Green River, Wyoming

Units-1000

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
1941	Jan.	22	0.73	16
	Feb.	19	.74	14
	Mar.	45	.69	31
	Apr.	95	.54	51
	May	174	.52	90
	June	342	.34	116
	July	137	.37	51
	Aug.	81	.46	37
	Sept.	48	.54	26
	Oct.	67	.60	40
	Nov.	53	.64	34
	Dec.	26	.81	21
	Total	1,109	.48	527
1942	Jan.	24	.79	19
	Feb.	23	.83	19
	Mar.	43	.70	30
	Apr.	200	.41	82
	May	151	.50	75
	June	337	.34	114
	July	205	.32	66
	Aug.	58	.52	30
	Sept.	32	.62	20
	Oct.	29	.76	22
	Nov.	26	.81	21
	Dec.	26	.77	20
	Total	1,154	.45	518
1943	Jan.	28	.78	22
	Feb.	29	.76	22
	Mar.	59	.63	37
	Apr.	200	.41	82
	May	237	.39	92
	June	476	.29	138
	July	359	.25	90
	Aug.	121	.39	47
	Sept.	50	.54	27
	Oct.	48	.67	32
	Nov.	43	.67	29
	Dec.	30	.77	23
	Total	1,680	.38	641
1944	Jan.	25	.80	20
	Feb.	25	.80	20
	Mar.	31	.77	24
	Apr.	267	.37	99
	May	155	.46	71
	June	351	.33	116
	July	230	.30	69
	Aug.	60	.50	30
	Sept.	31	.65	20
	Oct.	38	.71	27
	Nov.	31	.74	23
	Dec.	21	.81	17
	Total	1,265	.42	536
1945	Jan.	24	.79	19
	Feb.	27	.74	20
	Mar.	41	.68	28
	Apr.	78	.58	45
	May	111	.52	58
	June	245	.38	93
	July	284	.28	80
	Aug.	125	.39	49
	Sept.	76	.45	34
	Oct.	64	.62	40
	Nov.	42	.69	29
	Dec.	33	.73	24
	Total	1,150	.45	519
1946	Jan.	32	.75	24
	Feb.	26	.77	20
	Mar.	65	.62	40
	Apr.	131	.48	63
	May	212	.41	87
	June	320	.34	109
	July	153	.35	54
	Aug.	74	.47	35
	Sept.	52	.52	27
	Oct.	58	.64	37
	Nov.	51	.67	34
	Dec.	51	.67	34
	Total	1,225	.46	564
1947	Jan.	26	0.81	21
	Feb.	30	.73	22
	Mar.	141	.47	66
	Apr.	75	.57	43
	May	368	.33	121
	June	501	.29	145
	July	327	.26	85
	Aug.	199	.32	64
	Sept.	81	.44	36
	Oct.	75	.59	44
	Nov.	59	.63	37
	Dec.	44	.68	30
	Total	1,926	.37	714
1948	Jan.	38	.71	27
	Feb.	33	.73	24
	Mar.	64	.62	40
	Apr.	95	.54	51
	May	187	.43	80
	June	396	.31	123
	July	121	.39	47
	Aug.	56	.52	29
	Sept.	32	.62	20
	Oct.	36	.72	26
	Nov.	29	.76	22
	Dec.	26	.81	21
	Total	1,113	.46	510
1949	Jan.	27	.78	21
	Feb.	24	.79	19
	Mar.	45	.69	31
	Apr.	104	.52	54
	May	211	.41	86
	June	372	.32	119
	July	179	.36	64
	Aug.	65	.48	31
	Sept.	38	.58	22
	Oct.	52	.65	34
	Nov.	54	.65	35
	Dec.	34	.74	25
	Total	1,205	.45	541
1950	Jan.	29	.79	23
	Feb.	33	.73	24
	Mar.	102	.53	54
	Apr.	251	.38	95
	May	270	.37	100
	June	582	.34	198
	July	427	.23	98
	Aug.	140	.37	52
	Sept.	76	.45	34
	Oct.	66	.61	40
	Nov.	71	.59	42
	Dec.	49	.65	32
	Total	2,096	.38	792
1951	Jan.	34	.74	25
	Feb.	47	.66	31
	Mar.	70	.59	41
	Apr.	154	.45	69
	May	317	.35	111
	June	528	.28	148
	July	349	.25	87
	Aug.	208	.28	58
	Sept.	91	.43	39
	Oct.	81	.53	43
	Nov.	50	.68	34
	Dec.	43	.70	30
	Total	1,972	.36	716
1952	Jan.	41	.63	26
	Feb.	42	.62	26
	Mar.	52	.63	33
	Apr.	190	.52	99
	May	348	.32	111
	June	399	.27	108
	July	171	.33	56
	Aug.	99	.38	38
	Sept.	57	.51	29
	Oct.	42	.64	27
	Nov.	28	.82	23
	Dec.	27	.78	21
	Total	1,496	.40	597
1953	Jan.	32	0.69	22
	Feb.	33	.70	23
	Mar.	44	.68	30
	Apr.	77	.58	45
	May	74	.57	42
	June	381	.28	107
	July	206	.29	60
	Aug.	104	.39	41
	Sept.	39	.56	22
	Oct.	34	.74	25
	Nov.	36	.75	27
	Dec.	24	.88	21
	Total	1,084	.43	465
1954	Jan.	26	.81	21
	Feb.	27	.74	20
	Mar.	48	.67	32
	Apr.	88	.55	48
	May	282	.28	79
	June	232	.30	70
	July	250	.25	62
	Aug.	86	.40	34
	Sept.	47	.55	26
	Oct.	40	.68	27
	Nov.	39	.69	27
	Dec.	18	.89	16
	Total	1,183	.39	462
1955	Jan.	20	.80	16
	Feb.	20	.80	16
	Mar.	33	.76	25
	Apr.	74	.59	44
	May	127	.39	50
	June	245	.27	66
	July	116	.36	42
	Aug.	68	.41	28
	Sept.	35	.57	20
	Oct.	33	.70	23
	Nov.	28	.79	22
	Dec.	39	.74	29
	Total	898	.45	381
1956	Jan.	42	.69	29
	Feb.	29	.66	19
	Mar.	91	.56	51
	Apr.	158	.45	71
	May	310	.37	115
	June	555	.25	139
	July	197	.31	61
	Aug.	98	.38	37
	Sept.	41	.56	23
	Oct.	39	.59	23
	Nov.	35	.69	24
	Dec.	26	.77	20
	Total	1,621	.38	612
1957	Jan.	22	.77	17
	Feb.	37	.70	26
	Mar.	57	.68	39
	Apr.	60	.62	37
	May	176	.46	81
	June	476	.27	129
	July	380	.25	95
	Aug.	117	.35	41
	Sept.	68	.47	32
	Oct.	66	.55	36
	Nov.	48	.67	32
	Dec.	41	.71	29
	Total	1,548	.38	594
1958	Jan.	33	.76	25
	Feb.	47	.66	31
	Mar.	51	.63	32
	Apr.	99	.56	55
	May	291	.31	90
	June	266	.31	82
	July	76	.45	34
	Aug.	51	.53	27
	Sept.	36	.64	23
	Oct.	33	.79	26
	Nov.	32	.78	25
	Dec.	31	.74	23
	Total	1,046	.45	473

To obtain mg/l multiply T/AF by 735

Table 1

Colorado River Basin

Historical Flow and Quality of Water Data

Green River near Green River, Wyoming

Units-1000

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)	Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)	Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
	Jan.	24	0.71	17		Jan.	28	0.79	22		Jan.			
	Feb.	25	.72	18		Feb.	30	.70	21		Feb.			
	Mar.	49	.65	32		Mar.	38	.74	28		Mar.			
	Apr.	73	.64	47		Apr.	44	.86	38		Apr.			
	May	79	.51	40		May	94	.60	56		May			
	June	322	.26	84		June	429	.38	163		June			
1959	July	140	.34	48	1965	July	466	.30	140		July			
	Aug.	79	.40	32		Aug.	184	.36	66		Aug.			
	Sept.	42	.55	23		Sept.	461	.41	189		Sept.			
	Oct.	51	.57	29		Oct.	86	.73	63		Oct.			
	Nov.	42	.60	25		Nov.	75	.65	49		Nov.			
	Dec.	27	.74	20		Dec.	29	.90	26		Dec.			
	Total	953	.44	415		Total	1,964	.44	861		Total			
	Jan.	27	.74	20		Jan.	37	.76	28		Jan.			
	Feb.	23	.78	18		Feb.	35	.77	27		Feb.			
	Mar.	75	.53	40		Mar.	88	.72	63		Mar.			
	Apr.	84	.49	41		Apr.	118	.50	60		Apr.			
	May	66	.48	32		May	160	.39	62		May			
	June	173	.30	52		June	171	.31	53		June			
1960	July	68	.43	29	1966	July	91	.43	39		July			
	Aug.	38	.45	17		Aug.	56	.52	29		Aug.			
	Sept.	28	.54	15		Sept.	45	.60	27		Sept.			
	Oct.	42	.57	24		Oct.	35	.77	27		Oct.			
	Nov.	47	.49	23		Nov.	30	.83	25		Nov.			
	Dec.	27	.69	19		Dec.	25	.96	24		Dec.			
	Total	698	.47	330		Total	911	.52	473		Total			
	Jan.	20	.60	12		Jan.	19	1.01	19		Jan.			
	Feb.	19	.58	11		Feb.	19	1.04	20		Feb.			
	Mar.	30	.57	17		Mar.	33	.87	29		Mar.			
	Apr.	50	.60	30		Apr.	129	.54	70		Apr.			
	May	60	.43	26		May	138	.48	66		May			
	June	162	.27	44		June	456	.28	128		June			
1961	July	47	.43	20	1967	July	448	.25	112		July			
	Aug.	35	.43	15		Aug.	88	.39	34		Aug.			
	Sept.	39	.46	18		Sept.	65	.50	32		Sept.			
	Oct.	41	.51	21		Oct.	62	.56	35		Oct.			
	Nov.	29	.52	15		Nov.	49	.64	31		Nov.			
	Dec.	27	.52	14		Dec.	17	1.07	18		Dec.			
	Total	559	.43	243		Total	1,523	.39	594		Total			
	Jan.	32	.47	15		Jan.	17	1.02	18		Jan.			
	Feb.	48	.48	23		Feb.	16	1.03	16		Feb.			
	Mar.	77	.51	38		Mar.	33	.76	28		Mar.			
	Apr.	203	.43	87		Apr.	31	.93	29		Apr.			
	May	256	.36	92		May	56	.68	38		May			
	June	355	.27	96		June	271	.40	108		June			
1962	July	250	.27	68	1968	July	88	.41	36		July			
	Aug.	94	.37	35		Aug.	136	.40	54		Aug.			
	Sept.	38	.58	22		Sept.	126	.37	47		Sept.			
	Oct.	38	.63	24		Oct.	117	.44	51		Oct.			
	Nov.	35	.66	23		Nov.	54	.58	31		Nov.			
	Dec.	25	.88	22		Dec.	30	.85	26		Dec.			
	Total	1,451	.38	545		Total	975	.49	482		Total			
	Jan.	18	.72	13		Jan.					Jan.			
	Feb.	18	.72	13		Feb.					Feb.			
	Mar.	42	.67	28		Mar.					Mar.			
	Apr.	51	.63	32		Apr.					Apr.			
	May	100	.45	45		May					May			
	June	337	.26	88		June					June			
1963	July	143	.32	46		July					July			
	Aug.	76	.47	36		Aug.					Aug.			
	Sept.	77	.43	33		Sept.					Sept.			
	Oct.	58	.50	29		Oct.					Oct.			
	Nov.	52	.60	31		Nov.					Nov.			
	Dec.	30	.60	18		Dec.					Dec.			
	Total	1,002	.41	412		Total					Total			
	Jan.	23	.56	13		Jan.					Jan.			
	Feb.	22	.59	13		Feb.					Feb.			
	Mar.	29	.59	17		Mar.					Mar.			
	Apr.	68	.56	38		Apr.					Apr.			
	May	138	.32	44		May					May			
	June	323	.38	123		June					June			
1964	July	335	.26	87		July					July			
	Aug.	87	.39	34		Aug.					Aug.			
	Sept.	37	.65	24		Sept.					Sept.			
	Oct.	24	.92	22		Oct.					Oct.			
	Nov.	25	.88	22		Nov.					Nov.			
	Dec.	25	.84	21		Dec.					Dec.			
	Total	1,136	.40	458		Total					Total			

To obtain mg/l multiply T/AF by 735

Table I

Colorado River Basin
Flow and Quality of Water Data
Green River near Green River, Wyoming
(Annual Summary)

Units — 1000

Year	Flow (A.F.)	Concentration (T./A.F.)	Concentration (Mg./l)	T.D.S. (Tons)
1941	1,109	0.48	349	527
1942	1,154	.45	330	518
1943	1,680	.38	280	641
1944	1,265	.42	311	536
1945	1,150	.45	332	519
1946	1,225	.46	338	564
1947	1,926	.37	272	714
1948	1,113	.46	337	510
1949	1,205	.45	330	541
1950	2,096	.38	278	792
1951	1,972	.36	267	716
1952	1,496	.40	293	597
1953	1,084	.43	315	465
1954	1,183	.39	287	462
1955	838	.45	334	381
1956	1,621	.38	277	612
1957	1,548	.38	282	594
1958	1,046	.45	332	473
1959	953	.44	320	415
1960	698	.47	347	330
1961	559	.43	319	243
1962	1,451	.38	276	545
1963	1,002	.41	302	412
1964	1,136	.40	296	458
1965	1,964	.44	322	861
1966	911	.52	382	473
1967	1,523	.39	287	594
1968	975	.49	363	482
Total	35,883			14,975
Average	1,282	.42	307	535

Sampled quality record May 1951 to December 1968; remainder by correlation.

Measured flow record January 1941 to September 1945; and April 1951 to December 1968; remainder by correlation.

Table 2

Colorado River Basin

Historical Flow and Quality of Water Data

Green River near Greendale, Utah

Units-1000

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)	Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)	Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
	Jan.	27	0.93	25		Jan.	32	0.81	26		Jan.	48	0.81	39
	Feb.	25	1.16	29		Feb.	37	.89	33		Feb.	48	.85	41
	Mar.	72	.94	68		Mar.	195	.62	120		Mar.	73	.86	63
	Apr.	131	.56	74		Apr.	136	.62	84		Apr.	96	.76	73
	May	276	.58	160		May	521	.40	210		May	110	.64	70
	June	441	.40	175		June	628	.36	225		June	452	.39	175
-1941	July	171	.55	94	-1947	July	372	.35	131	-1953	July	198	.39	77
	Aug.	110	.73	80		Aug.	218	.45	99		Aug.	105	.54	57
	Sept.	67	.78	52		Sept.	91	.53	48		Sept.	43	.63	27
	Oct.	94	.97	91		Oct.	90	.70	63		Oct.	35	.89	31
	Nov.	71	.93	66		Nov.	71	.77	55		Nov.	42	.98	41
	Dec.	36	1.19	43		Dec.	56	.87	49		Dec.	32	.97	31
Total		1,521	.63	957	Total		2,447	.47	1,143	Total		1,282	.57	725
	Jan.	30	1.00	30		Jan.	47	.91	43		Jan.	28	1.11	31
	Feb.	31	1.00	31		Feb.	40	.88	35		Feb.	39	.87	34
	Mar.	69	1.07	74		Mar.	102	.79	81		Mar.	62	.81	50
	Apr.	261	.65	170		Apr.	157	.70	110		Apr.	101	.65	66
	May	235	.76	180		May	336	.38	126		May	302	.31	94
	June	434	.44	193		June	454	.36	162		June	223	.36	81
-1942	July	239	.40	97	-1948	July	126	.50	63	-1954	July	265	.28	73
	Aug.	73	.57	42		Aug.	59	.56	33		Aug.	81	.43	35
	Sept.	40	.72	29		Sept.	33	.76	25		Sept.	45	.69	31
	Oct.	36	1.00	36		Oct.	39	.77	30		Oct.	42	.95	40
	Nov.	35	1.17	41		Nov.	34	.85	29		Nov.	41	.85	35
	Dec.	34	1.06	36		Dec.	31	1.00	31		Dec.	20	1.05	21
Total		1,517	.63	959	Total		1,458	.53	768	Total		1,249	.47	591
	Jan.	33	1.09	36		Jan.	31	.90	28		Jan.	24	.75	18
	Feb.	37	.97	36		Feb.	29	.93	27		Feb.	24	.71	17
	Mar.	96	.74	71		Mar.	73	.89	65		Mar.	44	1.11	49
	Apr.	262	.48	125		Apr.	152	.69	105		Apr.	106	.64	68
	May	338	.38	130		May	310	.53	165		May	168	.52	88
	June	552	.33	182		June	493	.47	230		June	288	.33	95
-1943	July	393	.29	115	-1949	July	205	.52	106	-1955	July	130	.38	49
	Aug.	163	.47	76		Aug.	72	.61	44		Aug.	80	.52	42
	Sept.	64	.56	36		Sept.	42	.74	31		Sept.	38	.58	22
	Oct.	60	.72	43		Oct.	70	.93	65		Oct.	38	.68	26
	Nov.	54	.83	45		Nov.	66	.97	64		Nov.	36	.75	27
	Dec.	37	.89	33		Dec.	40	.97	39		Dec.	45	.82	37
Total		2,089	.44	928	Total		1,583	.61	969	Total		1,021	.53	538
	Jan.	30	.93	28		Jan.	36	1.19	43		Jan.	50	.86	43
	Feb.	32	1.00	32		Feb.	45	.95	43		Feb.	38	.76	29
	Mar.	48	1.48	71		Mar.	150	.61	92		Mar.	150	.47	70
	Apr.	345	.55	190		Apr.	323	.46	150		Apr.	203	.43	87
	May	245	.58	142		May	416	.46	190		May	368	.39	144
	June	469	.37	174		June	741	.37	275		June	615	.29	178
-1944	July	278	.39	109	-1950	July	458	.34	154	-1956	July	207	.33	69
	Aug.	76	.49	37		Aug.	153	.51	78		Aug.	104	.42	44
	Sept.	36	.61	22		Sept.	86	.62	53		Sept.	48	.44	21
	Oct.	47	.83	39		Oct.	76	.72	55		Oct.	46	.74	34
	Nov.	39	.92	36		Nov.	80	.75	60		Nov.	39	.82	32
	Dec.	27	.85	23		Dec.	61	.84	51		Dec.	26	.88	23
Total		1,672	.54	903	Total		2,625	.47	1,244	Total		1,894	.41	774
	Jan.	29	.97	28		Jan.	45	.80	36		Jan.	28	.86	24
	Feb.	34	.94	32		Feb.	61	.82	50		Feb.	43	.79	34
	Mar.	65	.88	57		Mar.	93	.78	73		Mar.	66	.91	60
	Apr.	113	.70	79		Apr.	212	.47	100		Apr.	86	.67	58
	May	176	.60	105		May	395	.45	177		May	275	.54	148
	June	310	.46	144		June	626	.36	225		June	685	.37	251
-1945	July	325	.37	120	-1951	July	366	.36	132	-1957	July	433	.36	155
	Aug.	174	.47	82		Aug.	228	.44	101		Aug.	142	.57	81
	Sept.	103	.43	44		Sept.	98	.56	55		Sept.	82	.58	48
	Oct.	74	.74	55		Oct.	99	.71	70		Oct.	77	.69	53
	Nov.	52	.88	46		Nov.	57	.91	52		Nov.	57	1.00	57
	Dec.	42	.81	34		Dec.	54	.87	47		Dec.	46	.91	42
Total		1,497	.55	826	Total		2,334	.48	1,118	Total		2,020	.50	1,011
	Jan.	39	.90	35		Jan.	49	.82	40		Jan.	43	.77	33
	Feb.	33	.85	28		Feb.	52	.81	42		Feb.	55	.80	44
	Mar.	88	.67	59		Mar.	63	.75	47		Mar.	66	.71	47
	Apr.	237	.48	115		Apr.	318	.62	198		Apr.	134	.67	90
	May	298	.44	130		May	600	.39	235		May	386	.39	151
	June	354	.37	133		June	554	.36	201		June	335	.38	127
-1946	July	162	.40	64	-1952	July	205	.56	114	-1958	July	87	.50	44
	Aug.	81	.57	46		Aug.	121	.60	72		Aug.	57	.56	32
	Sept.	62	.60	37		Sept.	67	.67	45		Sept.	39	.69	27
	Oct.	68	.76	52		Oct.	49	.86	42		Oct.	36	.72	26
	Nov.	63	.82	52		Nov.	37	1.11	41		Nov.	34	.70	24
	Dec.	62	.77	48		Dec.	34	1.18	40		Dec.	38	.84	32
Total		1,547	.52	799	Total		2,149	.52	1,117	Total		1,310	.52	677

To obtain mg/l multiply T/AF by 735.

Table 2
Colorado River Basin
Historical Flow and Quality of Water Data
Green River near Greendale, Utah
Units-1000

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
	Jan.	29	0.86	25
	Feb.	32	.91	29
	Mar.	65	.92	60
	Apr.	98	.71	70
	May	115	.57	66
	June	368	.36	132
-1959	July	176	.51	90
	Aug.	93	.47	44
	Sept.	58	.79	46
	Oct.	68	.72	49
	Nov.	51	.76	39
	Dec.	37	.99	37
	Total	1,190	.58	687
	Jan.	26	.81	21
	Feb.	29	.86	25
	Mar.	149	.70	104
	Apr.	140	.55	77
	May	127	.58	74
	June	216	.43	93
-1960	July	78	.49	38
	Aug.	43	.47	20
	Sept.	35	.56	20
	Oct.	40	.65	32
	Nov.	54	.67	36
	Dec.	27	.84	23
	Total	973	.58	563
	Jan.	27	.73	20
	Feb.	27	.77	21
	Mar.	64	.86	55
	Apr.	76	.69	52
	May	79	.59	47
	June	192	.32	61
-1961	July	56	.44	25
	Aug.	43	.58	25
	Sept.	55	.68	37
	Oct.	64	.70	45
	Nov.	54	.70	38
	Dec.	44	.78	34
	Total	781	.59	460
	Jan.	43	.65	28
	Feb.	83	.81	67
	Mar.	150	.84	126
	Apr.	374	.55	206
	May	394	.41	162
	June	456	.40	182
-1962	July	297	.39	116
	Aug.	109	.48	52
	Sept.	44	.64	28
	Oct.	48	.79	38
	Nov.	5	.80	4
	Dec.	16	.94	15
	Total	2,019	.51	1,024
	Jan.	23	.91	21
	Feb.	26	.92	24
	Mar.	6	.83	5
	Apr.	8	.87	7
	May	8	.87	7
	June	7	.86	6
-1963	July	6	.83	5
	Aug.	6	.83	5
	Sept.	7	.86	6
	Oct.	8	.87	7
	Nov.	19	.58	11
	Dec.	46	.63	29
	Total	170	.78	133
	Jan.	58	.57	33
	Feb.	56	.57	32
	Mar.	37	.59	22
	Apr.	35	.63	22
	May	91	.64	58
	June	86	.60	52
-1964	July	150	.61	92
	Aug.	122	.61	74
	Sept.	131	.61	80
	Oct.	159	.64	102
	Nov.	139	.60	83
	Dec.	194	.62	120
	Total	1,258	.61	770

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
	Jan.	216	0.63	136
	Feb.	213	.70	149
	Mar.	233	1.05	245
	Apr.	204	.83	169
	May	66	.80	53
	June	86	.86	74
-1965	July	29	.86	25
	Aug.	31	.87	27
	Sept.	44	.89	39
	Oct.	79	.79	62
	Nov.	120	.73	88
	Dec.	116	.65	75
	Total	1,437	.79	1,142
	Jan.	72	.64	46
	Feb.	72	.65	47
	Mar.	71	.76	54
	Apr.	130	.79	103
	May	83	.78	65
	June	95	.76	72
-1966	July	104	.75	78
	Aug.	118	.72	85
	Sept.	124	.73	91
	Oct.	124	.77	95
	Nov.	85	.81	69
	Dec.	111	.76	84
	Total	1,189	.75	889
	Jan.	142	.74	105
	Feb.	96	.75	72
	Mar.	67	.77	52
	Apr.	85	.81	69
	May	122	.83	101
	June	195	.83	[illegible]
-1967	July	171	.85	145
	Aug.	188	.86	162
	Sept.	180	.82	148
	Oct.	188	.87	164
	Nov.	173	.85	147
	Dec.	197	.72	142
	Total	1804	.81	1469
	Jan.	187	.70	131
	Feb.	123	.72	89
	Mar.	76	.83	63
	Apr.	96	.88	84
	May	119	.81	96
	June	97	.77	75
-1968	July	198	.75	148
	Aug.	200	.75	150
	Sept.	181	.75	136
	Oct.	140	.73	102
	Nov.	137	.68	93
	Dec.	137	.68	93
	Total	1691	.75	1260
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			

To obtain mg/l multiply T/AF by 735.

Table 2

Colorado River Basin
Flow and Quality of Water Data
Green River near Greendale, Utah
(Annual Summary)

Units —1000

Year	Flow (A.F.)	Concentration (T./A.F.)	(Mg./l)	T.D.S. (Tons)
1941	1,521	0.63	462	957
1942	1,517	.63	465	959
1943	2,089	.44	327	928
1944	1,672	.54	397	903
1945	1,497	.55	406	826
1946	1,547	.52	380	799
1947	2,447	.47	343	1,143
1948	1,458	.53	387	768
1949	1,583	.61	450	969
1950	2,625	.47	348	1,244
1951	2,334	.48	352	1,118
1952	2,149	.52	382	1,117
1953	1,282	.57	416	725
1954	1,249	.47	348	591
1955	1,021	.53	387	538
1956	1,894	.41	300	774
1957	2,020	.50	368	1,011
1958	1,310	.52	380	677
1959	1,190	.58	424	687
1960	973	.58	425	563
1961	781	.59	433	460
1962	2,019	.51	373	1,024
1963	170	.78	575	133
1964	1,258	.61	450	770
1965	1,437	.79	584	1,142
1966	1,189	.75	550	889
1967	1,804	.81	599	1,469
1968	1,691	.75	548	1,260
Total	43,727			24,444
Average	1,562	.56	411	873

Sampled quality record October 1956 to December 1968 (fragmentary); remainder by correlation.

Measured flow record entire period.

Table 3
Colorado River Basin
Historical Flow and Quality of Water Data
Duchesne River near Randlett, Utah
Units - 1000

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
1941	Jan.	25	1.12	28
	Feb.	24	1.29	31
	Mar.	21	1.71	36
	Apr.	20	1.50	30
	May	155	.50	78
	June	232	.38	88
	July	35	1.11	39
	Aug.	18	1.50	27
	Sept.	15	1.60	24
	Oct.	54	.93	50
	Nov.	51	.90	46
	Dec.	44	1.04	46
	Total	694	.75	523
1942	Jan.	40	.90	36
	Feb.	39	1.00	39
	Mar.	39	1.23	48
	Apr.	50	.90	45
	May	83	.72	60
	June	171	.46	79
	July	23	1.43	33
	Aug.	8	2.12	17
	Sept.	5	2.40	12
	Oct.	18	1.50	27
	Nov.	22	1.41	31
	Dec.	28	1.28	36
	Total	526	.88	463
1943	Jan.	26	1.12	29
	Feb.	29	1.17	34
	Mar.	29	1.51	44
	Apr.	43	1.00	43
	May	100	.64	64
	June	103	.62	64
	July	28	1.21	34
	Aug.	23	1.39	32
	Sept.	8	2.00	16
	Oct.	22	1.40	31
	Nov.	24	1.29	31
	Dec.	25	1.28	32
	Total	460	.99	454
1944	Jan.	23	1.08	25
	Feb.	26	1.31	34
	Mar.	43	1.20	52
	Apr.	48	.94	45
	May	128	.57	73
	June	255	.37	94
	July	82	.72	59
	Aug.	8	2.00	16
	Sept.	7	2.14	15
	Oct.	24	1.37	33
	Nov.	26	1.30	34
	Dec.	28	1.32	37
	Total	698	.74	517
1945	Jan.	30	1.00	30
	Feb.	27	1.18	32
	Mar.	32	1.40	45
	Apr.	24	1.29	31
	May	59	.86	51
	June	91	.67	61
	July	30	1.23	37
	Aug.	31	1.19	37
	Sept.	12	1.75	21
	Oct.	21	1.38	29
	Nov.	26	1.27	33
	Dec.	24	1.37	33
	Total	407	1.08	440
1946	Jan.	23	1.13	26
	Feb.	21	1.38	29
	Mar.	29	1.41	41
	Apr.	40	1.00	40
	May	70	.78	55
	June	47	.95	45
	July	5	2.60	13
	Aug.	6	2.33	14
	Sept.	4	2.75	11
	Oct.	17	1.53	26
	Nov.	32	1.22	39
	Dec.	30	1.20	36
	Total	324	1.16	375
1947	Jan.	26	1.07	28
	Feb.	36	1.08	39
	Mar.	36	1.27	46
	Apr.	23	1.30	30
	May	143	.53	76
	June	158	.49	78
	July	33	1.18	39
	Aug.	25	1.28	32
	Sept.	12	1.75	21
	Oct.	17	1.65	28
	Nov.	29	1.21	35
	Dec.	31	1.19	37
	Total	569	.86	489
1948	Jan.	29	1.00	29
	Feb.	26	1.31	34
	Mar.	40	1.20	48
	Apr.	31	1.23	38
	May	70	.79	55
	June	51	.92	47
	July	3	3.00	9
	Aug.	2	3.50	7
	Sept.	1	3.00	3
	Oct.	5	2.40	12
	Nov.	14	1.71	24
	Dec.	26	1.27	33
	Total	298	1.14	339
1949	Jan.	24	1.08	26
	Feb.	23	1.30	30
	Mar.	44	1.20	53
	Apr.	46	.98	45
	May	127	.56	71
	June	230	.39	90
	July	50	.94	47
	Aug.	7	2.14	15
	Sept.	8	2.13	17
	Oct.	25	1.28	32
	Nov.	20	1.31	35
	Dec.	28	1.29	36
	Total	641	.78	497
1950	Jan.	31	1.00	31
	Feb.	26	1.23	32
	Mar.	40	1.30	52
	Apr.	44	1.00	44
	May	97	.67	65
	June	193	.43	83
	July	45	1.00	45
	Aug.	9	2.00	18
	Sept.	13	1.77	23
	Oct.	16	1.56	25
	Nov.	27	1.26	34
	Dec.	33	1.36	45
	Total	574	.87	497
1951	Jan.	26	1.00	26
	Feb.	26	1.31	34
	Mar.	23	1.56	36
	Apr.	14	1.71	24
	May	79	.75	59
	June	124	.73	91
	July	31	1.29	40
	Aug.	26	1.46	38
	Sept.	10	1.90	19
	Oct.	25	1.28	32
	Nov.	32	1.22	39
	Dec.	32	1.22	39
	Total	448	1.06	477
1952	Jan.	28	1.07	30
	Feb.	26	1.31	34
	Mar.	31	1.42	44
	Apr.	111	.60	67
	May	304	.34	103
	June	302	.33	100
	July	70	.79	55
	Aug.	49	.94	46
	Sept.	30	1.20	36
	Oct.	21	1.38	29
	Nov.	26	1.31	34
	Dec.	37	1.11	41
	Total	1,035	.60	619
1953	Jan.	39	0.90	35
	Feb.	33	1.12	37
	Mar.	34	1.41	48
	Apr.	13	1.77	23
	May	15	1.60	24
	June	107	.60	64
	July	13	1.77	23
	Aug.	12	1.75	21
	Sept.	5	2.20	11
	Oct.	9	2.00	18
	Nov.	20	1.40	28
	Dec.	26	1.31	34
	Total	326	1.12	366
1954	Jan.	27	1.11	30
	Feb.	25	1.28	32
	Mar.	20	1.80	36
	Apr.	13	1.77	23
	May	36	1.11	40
	June	5	2.40	12
	July	2	3.00	6
	Aug.	1	4.00	4
	Sept.	6	2.33	14
	Oct.	17	1.59	27
	Nov.	18	1.50	27
	Dec.	18	1.50	27
	Total	188	1.48	278
1955	Jan.	25	1.08	27
	Feb.	21	1.43	30
	Mar.	34	1.38	47
	Apr.	22	1.41	31
	May	45	1.00	45
	June	34	1.09	37
	July	2	3.00	6
	Aug.	8	2.25	17
	Sept.	4	2.50	10
	Oct.	6	2.33	14
	Nov.	15	1.60	24
	Dec.	29	1.21	35
	Total	245	1.32	323
1956	Jan.	27	1.00	27
	Feb.	23	1.35	31
	Mar.	25	1.60	40
	Apr.	17	1.59	27
	May	74	.76	56
	June	90	.68	61
	July	4	2.75	11
	Aug.	2	4.00	8
	Sept.	1	5.00	5
	Oct.	4	2.25	9
	Nov.	17	1.59	27
	Dec.	19	1.21	23
	Total	303	1.07	325
1957	Jan.	21	1.05	22
	Feb.	20	1.05	21
	Mar.	22	1.54	34
	Apr.	12	1.83	22
	May	39	1.23	48
	June	184	.41	75
	July	35	.91	32
	Aug.	18	1.61	29
	Sept.	15	1.47	22
	Oct.	19	1.74	33
	Nov.	41	1.41	58
	Dec.	30	1.07	32
	Total	456	.94	428
1958	Jan.	29	.83	24
	Feb.	31	1.00	31
	Mar.	35	1.37	48
	Apr.	29	1.07	31
	May	141	.46	65
	June	103	.42	43
	July	4	2.50	10
	Aug.	1	4.00	4
	Sept.	3	2.33	7
	Oct.	5	2.60	13
	Nov.	14	1.93	27
	Dec.	21	1.24	26
	Total	416	.79	329

To obtain mg/l multiply T/AF by 735

Table 3

Colorado River Basin

Historical Flow and Quality of Water Data

Duchesne River near Randlett, Utah

Units - 1000

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
1959	Jan.	22	1.14	25
	Feb.	24	1.04	25
	Mar.	17	1.29	22
	Apr.	5	2.00	10
	May	4	2.75	11
	June	34	.85	29
	July	6	2.00	12
	Aug.	4	2.75	11
	Sept.	4	2.50	10
	Oct.	11	1.54	17
	Nov.	13	1.54	20
	Dec.	22	1.32	29
	Total	166	1.33	221
1960	Jan.	23	.87	20
	Feb.	23	.83	19
	Mar.	27	1.15	31
	Apr.	8	1.62	13
	May	18	1.17	21
	June	23	.91	21
	July	1	4.00	4
	Aug.	1	4.00	4
	Sept.	1	4.00	4
	Oct.	5	2.40	12
	Nov.	12	1.58	19
	Dec.	18	1.33	24
	Total	160	1.20	192
1961	Jan.	21	1.19	25
	Feb.	19	1.47	28
	Mar.	10	1.50	15
	Apr.	2	3.50	7
	May	3	2.33	7
	June	3	2.67	8
	July	1	4.00	4
	Aug.	1	3.00	3
	Sept.	13	1.15	15
	Oct.	19	1.47	28
	Nov.	27	1.11	30
	Dec.	26	1.00	26
	Total	145	1.35	106
1962	Jan.	21	.81	17
	Feb.	43	.93	40
	Mar.	49	1.04	51
	Apr.	70	.69	48
	May	88	.64	56
	June	146	.47	69
	July	27	1.04	28
	Aug.	4	2.75	11
	Sept.	4	2.50	10
	Oct.	15	1.73	26
	Nov.	15	1.60	24
	Dec.	23	1.26	29
	Total	505	.81	409
1963	Jan.	18	1.17	21
	Feb.	29	1.14	33
	Mar.	10	1.90	19
	Apr.	5	3.20	16
	May	31	.97	30
	June	50	.76	38
	July	3	2.67	8
	Aug.	5	2.40	12
	Sept.	14	1.64	23
	Oct.	7	2.43	17
	Nov.	16	1.62	26
	Dec.	22	1.14	25
	Total	210	1.28	268
1964	Jan.	18	1.00	18
	Feb.	18	.94	17
	Mar.	23	1.04	24
	Apr.	14	1.57	22
	May	72	.68	49
	June	122	.66	81
	July	29	.97	28
	Aug.	6	2.17	13
	Sept.	4	2.75	11
	Oct.	5	2.80	14
	Nov.	18	1.67	30
	Dec.	27	1.26	34
	Total	356	.96	341
1965	Jan.	27	1.00	27
	Feb.	21	1.38	29
	Mar.	26	1.54	40
	Apr.	32	1.16	37
	May	71	1.11	79
	June	302	.49	148
	July	175	.51	89
	Aug.	57	.96	55
	Sept.	58	1.09	63
	Oct.	47	1.15	54
	Nov.	47	1.13	53
	Dec.	42	1.12	47
	Total	905	.80	721
1966	Jan.	29	.90	25
	Feb.	38	.74	28
	Mar.	47	1.02	48
	Apr.	35	1.20	42
	May	58	1.07	62
	June	16	1.81	29
	July	3	3.00	9
	Aug.	3	3.00	9
	Sept.	6	2.50	15
	Oct.	11	2.36	26
	Nov.	19	1.79	34
	Dec.	31	1.35	42
	Total	306	1.24	379
1967	Jan.	33	1.01	33
	Feb.	30	.98	29
	Mar.	42	1.44	50
	Apr.	19	1.71	32
	May	56	.82	46
	June	253	.45	114
	July	76	.70	53
	Aug.	11	1.92	21
	Sept.	10	2.05	20
	Oct.	12	2.17	26
	Nov.	18	1.74	31
	Dec.	32	1.02	33
	Total	592	.84	497
1968	Jan.	34	.85	29
	Feb.	24	1.12	28
	Mar.	40	1.49	60
	Apr.	31	1.61	50
	May	45	1.14	51
	June	250	.40	100
	July	24	1.23	30
	Aug.	26	1.40	36
	Sept.	13	1.91	25
	Oct.	20	1.77	35
	Nov.	27	1.45	39
	Dec.	38	1.03	39
	Total	582	.91	532
	Jan.			
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	Dec.			
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	June			
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	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			

To obtain mg/l multiply T/AF by 735

Table 3

Colorado River Basin
Flow and Quality of Water Data
Duchesne River near Randlett, Utah
(Annual Summary)

Units — 1000

Year	Flow (A.F.)	Concentration (T./A.F.)	Concentration (Mg./l)	T.D.S. (Tons)
1941	694	0.75	554	523
1942	526	.88	647	463
1943	460	.99	725	454
1944	698	.74	544	517
1945	407	1.08	795	440
1946	324	1.16	851	375
1947	569	.86	632	489
1948	298	1.14	836	339
1949	641	.78	570	497
1950	574	.87	636	497
1951	448	1.06	783	477
1952	1,035	.60	440	619
1953	326	1.12	825	366
1954	188	1.48	1,087	278
1955	245	1.32	969	323
1956	303	1.07	788	325
1957	456	.94	690	428
1958	416	.79	581	329
1959	166	1.33	979	221
1960	160	1.20	882	192
1961	145	1.35	994	196
1962	505	.81	595	409
1963	210	1.28	938	268
1964	356	.96	704	341
1965	905	.80	586	721
1966	306	1.24	910	379
1967	591	.84	618	497
1968	582	.91	672	532
Total	12,534			11,495
Average	448	.92	674	411

Sampled quality record December 1950 to September 1951; November 1956 to December 1968; remainder by correlation.

Measured flow record October 1942 to December 1968; remainder by correlation.

Table 4
Colorado River Basin
Historical Flow and Quality of Water Data
Green River at Green River, Utah

Units - 1000

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
-1941	Jan.	100	1.01	101
	Feb.	126	1.06	134
	Mar.	216	1.01	218
	Apr.	314	.75	235
	May	1,172	.53	621
	June	1,146	.49	562
	July	359	.63	226
	Aug.	267	1.09	291
	Sept.	182	1.01	184
	Oct.	318	1.00	318
	Nov.	240	.90	216
	Dec.	168	.98	165
	Total	4,608	.71	3,271
-1942	Jan.	112	1.04	117
	Feb.	122	.98	120
	Mar.	264	.94	248
	Apr.	858	.65	557
	May	980	.57	558
	June	1,271	.39	496
	July	414	.57	236
	Aug.	152	.85	129
	Sept.	91	1.10	100
	Oct.	118	1.20	142
	Nov.	124	1.18	146
	Dec.	116	1.22	141
	Total	4,622	.65	2,989
-1943	Jan.	112	1.13	127
	Feb.	130	1.02	132
	Mar.	236	.91	215
	Apr.	569	.57	325
	May	763	.39	298
	June	1,074	.40	430
	July	612	.43	263
	Aug.	300	.83	249
	Sept.	116	.98	114
	Oct.	124	1.10	136
	Nov.	146	1.04	152
	Dec.	112	1.11	124
	Total	4,294	.60	2,565
-1944	Jan.	80	1.20	96
	Feb.	111	1.06	118
	Mar.	253	1.07	271
	Apr.	529	.81	428
	May	924	.48	444
	June	1,391	.30	417
	July	591	.44	260
	Aug.	143	.73	104
	Sept.	73	.96	70
	Oct.	115	1.13	130
	Nov.	119	1.14	136
	Dec.	88	1.23	108
	Total	4,417	.58	2,582
-1945	Jan.	109	1.04	113
	Feb.	128	.99	127
	Mar.	185	1.03	191
	Apr.	291	.84	244
	May	909	.44	400
	June	1,016	.39	396
	July	701	.41	287
	Aug.	335	.74	248
	Sept.	163	.77	125
	Oct.	161	.99	159
	Nov.	149	.99	148
	Dec.	113	1.06	120
	Total	4,260	.60	2,558
-1946	Jan.	123	.95	117
	Feb.	117	.91	106
	Mar.	236	.90	212
	Apr.	528	.60	317
	May	775	.41	318
	June	746	.36	269
	July	264	.47	124
	Aug.	152	.84	128
	Sept.	105	.91	96
	Oct.	149	1.00	149
	Nov.	170	.98	167
	Dec.	154	.94	145
	Total	3,519	.61	2,148
-1947	Jan.	92	1.07	98
	Feb.	151	.86	130
	Mar.	411	.79	325
	Apr.	422	.59	249
	May	1,400	.38	532
	June	1,348	.39	526
	July	656	.40	262
	Aug.	365	.71	259
	Sept.	166	.77	128
	Oct.	181	.91	165
	Nov.	179	.91	163
	Dec.	152	1.01	154
	Total	5,523	.54	2,991
-1948	Jan.	141	.94	132
	Feb.	136	.91	124
	Mar.	313	.86	269
	Apr.	558	.69	385
	May	1,061	.39	414
	June	952	.34	324
	July	268	.54	145
	Aug.	137	.81	111
	Sept.	69	.81	56
	Oct.	92	1.02	94
	Nov.	104	1.05	109
	Dec.	97	1.10	107
	Total	3,928	.58	2,270
-1949	Jan.	100	1.01	101
	Feb.	110	.92	101
	Mar.	276	.92	254
	Apr.	474	.69	327
	May	1,221	.43	525
	June	1,547	.42	650
	July	592	.57	338
	Aug.	172	.77	132
	Sept.	112	.89	100
	Oct.	207	.98	203
	Nov.	190	.90	171
	Dec.	128	1.07	137
	Total	5,129	.59	3,039
-1950	Jan.	141	1.01	142
	Feb.	147	1.01	148
	Mar.	356	.90	321
	Apr.	620	.64	397
	May	1,026	.53	544
	June	1,567	.35	548
	July	734	.49	360
	Aug.	246	.63	155
	Sept.	149	.89	133
	Oct.	153	.96	147
	Nov.	166	.99	164
	Dec.	171	.96	164
	Total	5,476	.59	3,223
-1951	Jan.	113	1.13	128
	Feb.	167	.92	154
	Mar.	204	.93	190
	Apr.	372	.70	260
	May	882	.45	397
	June	1,309	.40	524
	July	627	.43	270
	Aug.	379	.69	261
	Sept.	178	.79	140
	Oct.	211	.99	209
	Nov.	164	1.05	172
	Dec.	132	1.07	142
	Total	4,738	.60	2,847
-1952	Jan.	135	1.01	136
	Feb.	140	.96	134
	Mar.	160	1.05	168
	Apr.	988	.88	869
	May	2,087	.48	1,002
	June	1,809	.36	651
	July	514	.60	309
	Aug.	315	.89	280
	Sept.	184	.96	177
	Oct.	129	1.09	140
	Nov.	122	1.24	151
	Dec.	129	1.20	155
	Total	6,712	.62	4,172
-1953	Jan.	140	1.05	147
	Feb.	141	1.04	147
	Mar.	217	1.00	217
	Apr.	221	.96	212
	May	454	.55	250
	June	1,167	.37	432
	July	376	.48	181
	Aug.	212	.84	178
	Sept.	87	.99	86
	Oct.	86	1.20	104
	Nov.	126	1.15	145
	Dec.	107	1.18	126
	Total	3,334	.67	2,225
-1954	Jan.	107	1.09	117
	Feb.	138	1.03	142
	Mar.	169	1.03	174
	Apr.	270	.75	202
	May	639	.38	243
	June	376	.45	169
	July	346	.46	159
	Aug.	120	.65	78
	Sept.	134	1.02	137
	Oct.	139	1.14	159
	Nov.	120	1.06	127
	Dec.	80	1.25	100
	Total	2,638	.68	1,807
-1955	Jan.	80	1.06	85
	Feb.	86	.92	79
	Mar.	237	.92	218
	Apr.	311	.77	239
	May	678	.39	264
	June	654	.36	236
	July	223	.46	102
	Aug.	161	.83	134
	Sept.	71	.93	66
	Oct.	77	1.08	83
	Nov.	86	1.13	97
	Dec.	127	1.02	130
	Total	2,791	.62	1,733
-1956	Jan.	155	.91	141
	Feb.	100	1.05	105
	Mar.	314	.81	255
	Apr.	460	.53	244
	May	995	.35	348
	June	1,207	.32	386
	July	294	.49	144
	Aug.	169	.67	113
	Sept.	72	.72	52
	Oct.	77	.94	73
	Nov.	99	1.02	101
	Dec.	79	1.05	83
	Total	4 021	.51	2,045
-1957	Jan.	83	.95	79
	Feb.	100	.94	94
	Mar.	237	.89	210
	Apr.	290	.73	212
	May	913	.48	438
	June	1,871	.34	636
	July	1,164	.34	396
	Aug.	386	.79	305
	Sept.	202	.76	153
	Oct.	185	.94	174
	Nov.	228	.96	219
	Dec.	149	.97	144
	Total	5,808	.53	3,060
-1958	Jan.	128	.93	119
	Feb.	184	.86	158
	Mar.	246	.92	227
	Apr.	432	.71	307
	May	1,311	.41	537
	June	1,174	.35	411
	July	224	.62	139
	Aug.	110	.82	91
	Sept.	96	1.07	103
	Oct.	91	1.01	92
	Nov.	102	1.10	113
	Dec.	114	1.09	124
	Total	4,212	.57	2,421

To obtain mg/l multiply T/AF by 735.

Table 4
Colorado River Basin
Historical Flow and Quality of Water Data
Green River at Green River, Utah
Units - 1000

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
-1959	Jan.	97	1.13	110
	Feb.	114	.95	108
	Mar.	146	.94	137
	Apr.	219	.76	166
	May	480	.42	202
	June	763	.34	259
	July	346	.51	176
	Aug.	179	.90	161
	Sept.	104	.92	96
	Oct.	178	.86	153
	Nov.	152	.83	126
	Dec.	106	1.02	108
	Total	2,884	.62	1,802
-1960	Jan.	95	1.05	100
	Feb.	102	.95	97
	Mar.	320	.83	266
	Apr.	534	.51	272
	May	551	.39	215
	June	683	.33	225
	July	170	.52	88
	Aug.	69	.76	52
	Sept.	59	.93	55
	Oct.	96	1.00	96
	Nov.	105	.90	94
	Dec.	80	1.06	85
	Total	2,864	.57	1,645
-1961	Jan.	79	.98	77
	Feb.	94	.87	82
	Mar.	136	.89	121
	Apr.	184	.79	145
	May	342	.41	140
	June	542	.31	168
	July	112	.49	55
	Aug.	80	.91	73
	Sept.	175	.99	173
	Oct.	234	.75	176
	Nov.	161	.80	129
	Dec.	126	.88	111
	Total	2,265	.64	1,450
-1962	Jan.	115	.79	91
	Feb.	403	.72	290
	Mar.	401	.95	381
	Apr.	1,093	.56	612
	May	1,350	.36	486
	June	1,074	.38	408
	July	598	.41	245
	Aug.	177	.61	108
	Sept.	98	.98	96
	Oct.	126	1.37	173
	Nov.	94	1.15	108
	Dec.	72	1.10	79
	Total	5,601	.55	3,077
-1963	Jan.	71	1.04	74
	Feb.	120	.93	112
	Mar.	99	1.00	99
	Apr.	154	.68	105
	May	399	.40	160
	June	310	.42	130
	July	51	.77	39
	Aug.	72	1.77	127
	Sept.	95	1.57	149
	Oct.	47	1.32	62
	Nov.	74	1.26	93
	Dec.	84	1.08	91
	Total	1,576	.79	1,241
-1964	Jan.	109	.76	83
	Feb.	114	.76	87
	Mar.	128	.87	111
	Apr.	190	.89	169
	May	634	.45	285
	June	725	.40	290
	July	344	.54	186
	Aug.	196	.93	182
	Sept.	139	.82	114
	Oct.	196	.78	153
	Nov.	200	.84	168
	Dec.	267	.81	216
	Total	3,242	.63	2,044

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
-1965	Jan.	300	0.73	219
	Feb.	303	.82	248
	Mar.	361	.88	318
	Apr.	518	.79	409
	May	819	.46	377
	June	1,207	.42	507
	July	546	.52	284
	Aug.	228	.94	214
	Sept.	189	.95	180
	Oct.	253	.85	215
	Nov.	239	.92	220
	Dec.	248	.89	221
	Total	5,211	.65	3,412
-1966	Jan.	181	.86	156
	Feb.	166	.80	133
	Mar.	393	.80	314
	Apr.	390	.66	257
	May	566	.48	272
	June	325	.55	179
	July	147	.85	125
	Aug.	147	.96	141
	Sept.	157	1.01	159
	Oct.	189	1.01	191
	Nov.	159	1.06	169
	Dec.	146	1.12	164
	Total	2,966	.76	2,260
-1967	Jan.	196	.88	172
	Feb.	169	.90	152
	Mar.	256	.95	243
	Apr.	260	.77	200
	May	504	.54	272
	June	1,134	.52	590
	July	508	.63	320
	Aug.	247	.99	245
	Sept	231	1.06	245
	Oct.	250	1.07	268
	Nov.	243	1.03	250
	Dec.	229	1.31	300
	Total	4,227	.77	3,257
-1968	Jan.	249	.87	217
	Feb.	196	.91	178
	Mar.	241	1.05	253
	Apr.	275	.94	258
	May	708	.58	411
	June	1,248	.35	437
	July	426	.65	277
	Aug.	345	1.02	352
	Sept.	241	.93	224
	Oct.	230	.99	228
	Nov.	221	.93	206
	Dec.	209	.88	184
	Total	4,589	.70	3,225
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
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	Aug.			
	Sept.			
	Oct.			
	Nov.			
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	Total			
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	Total			
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	Nov.			
	Dec.			
	Total			
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			

To obtain mg/l multiply T/AF by 735.

Table 4
Colorado River Basin
Historical Flow and Quality of Water Data
Green River at Green River, Utah
(Annual Summary)

Units - 1000

Year	Flow (A.F.)	Concentration (T./A.F.)	Concentration (Mg./1)	T.D.S. (Tons)
1941	4,608	0.71	522	3,271
1942	4,622	.65	475	2,989
1943	4,294	.60	439	2,565
1944	4,417	.58	430	2,582
1945	4,260	.60	441	2,558
1946	3,519	.61	449	2,148
1947	5,523	.54	398	2,991
1948	3,928	.58	425	2,270
1949	5,129	.59	435	3,039
1950	5,476	.59	433	3,223
1951	4,738	.60	442	2,847
1952	6,712	.62	457	4,172
1953	3,334	.67	491	2,225
1954	2,638	.68	503	1,807
1955	2,791	.62	456	1,733
1956	4,021	.51	374	2,045
1957	5,808	.53	387	3,060
1958	4,212	.57	422	2,421
1959	2,884	.62	459	1,802
1960	2,864	.57	422	1,645
1961	2,265	.64	471	1,450
1962	5,601	.55	404	3,077
1963	1,576	.79	579	1,241
1964	3,242	.63	463	2,044
1965	5,211	.65	481	3,412
1966	2,966	.76	560	2,260
1967	4,227	.77	566	3,257
1968	4,589	.70	517	3,225
Total	115,455			71,359
Average	4,123	.62	454	2,549

Sampled quality record entire period.
Measured flow record entire period.

Table 5
Colorado River Basin
Historical Flow and Quality of Water Data
San Rafael River near Green River, Utah

Units - 1000

Year	Month	Flow (A.F.)	Concen- tration (T./A.F.)	T.D.S. (Tons)
-1941	Jan.	2	4.0	8
	Feb.	2	4.0	8
	Mar.	6	3.5	21
	Apr.	1	4.0	4
	May	50	1.2	62
	June	49	1.2	59
	July	7	2.9	20
	Aug.	6	3.3	20
	Sept.	2	4.5	9
	Oct.	5	4.0	20
	Nov.	5	4.2	21
	Dec.	4	4.0	16
Total		139	1.9	268
-1942	Jan.	6	2.8	17
	Feb.	5	3.6	18
	Mar.	6	3.7	22
	Apr.	14	2.8	39
	May	34	1.4	49
	June	51	1.2	61
	July	6	3.0	18
	Aug.	6	3.2	19
	Sept.	1	5.0	5
	Oct.	2	5.0	10
	Nov.	3	4.7	14
	Dec.	3	4.7	14
Total		137	2.1	286
-1943	Jan.	4	3.0	12
	Feb.	5	3.4	17
	Mar.	6	3.8	23
	Apr.	15	2.9	44
	May	13	2.1	27
	June	14	2.0	28
	July	2	3.5	7
	Aug.	6	3.2	19
	Sept.	1	5.0	5
	Oct.	2	5.0	10
	Nov.	2	5.0	10
	Dec.	3	3.7	11
Total		73	2.9	213
-1944	Jan.	2	3.5	7
	Feb.	3	3.0	9
	Mar.	6	3.5	21
	Apr.	1	5.0	5
	May	40	1.3	53
	June	72	1.1	78
	July	9	2.9	26
	Aug.	7	3.1	22
	Sept.	1	5.0	5
	Oct.	2	5.0	10
	Nov.	3	4.7	14
	Dec.	3	4.3	13
Total		149	1.8	263
-1945	Jan.	3	3.3	10
	Feb.	3	4.0	12
	Mar.	6	3.5	21
	Apr.	1	6.0	6
	May	22	1.6	35
	June	27	1.5	41
	July	6	3.2	19
	Aug.	7	3.4	24
	Sept.	2	4.0	8
	Oct.	3	5.0	15
	Nov.	3	4.7	14
	Dec.	2	4.5	9
Total		85	2.5	214
-1946	Jan.	2	4.0	8
	Feb.	4	3.3	13
	Mar.	6	3.7	22
	Apr.	11	3.2	35
	May	20	1.8	36
	June	8	2.4	19
	July	1	4.0	4
	Aug.	7	5.4	38
	Sept.	0	0	0
	Oct.	2	5.0	10
	Nov.	5	3.8	19
	Dec.	3	4.3	13
Total		69	3.1	217
-1947	Jan.	2	4.5	9
	Feb.	5	3.0	15
	Mar.	4	3.8	15
	Apr.	3	4.3	13
	May	33	1.4	46
	June	26	1.8	47
	July	5	3.6	18
	Aug.	20	3.4	68
	Sept.	3	5.0	15
	Oct.	2	6.0	12
	Nov.	4	3.8	15
	Dec.	4	3.5	14
Total		111	2.6	287
-1948	Jan.	3	3.7	11
	Feb.	6	3.0	18
	Mar.	7	3.6	25
	Apr.	4	3.5	14
	May	16	1.4	23
	June	13	2.2	29
	July	2	4.0	8
	Aug.	6	2.2	13
	Sept.	0	0	0
	Oct.	1	5.0	5
	Nov.	2	5.0	10
	Dec.	2	4.5	9
Total		62	2.7	166
-1949	Jan.	2	4.0	8
	Feb.	2	4.0	8
	Mar.	9	3.3	30
	Apr.	10	2.2	22
	May	30	1.3	38
	June	52	1.2	64
	July	14	2.7	38
	Aug.	5	3.0	15
	Sept.	3	4.7	14
	Oct.	3	4.7	14
	Nov.	3	4.7	14
	Dec.	2	4.5	9
Total		135	2.0	274
-1950	Jan.	2	4.5	9
	Feb.	6	3.3	20
	Mar.	5	4.0	20
	Apr.	3	4.7	14
	May	9	2.2	20
	June	11	2.2	24
	July	9	2.9	26
	Aug.	1	3.0	3
	Sept.	1	5.0	5
	Oct.	1	6.0	6
	Nov.	2	5.5	11
	Dec.	3	4.3	13
Total		53	3.2	171
-1951	Jan.	2	5.0	10
	Feb.	3	3.7	11
	Mar.	2	5.0	10
	Apr.	1	6.0	6
	May	15	1.9	29
	June	23	1.7	40
	July	3	3.7	11
	Aug.	12	2.2	27
	Sept.	1	5.0	5
	Oct.	6	4.0	24
	Nov.	4	4.5	18
	Dec.	3	5.0	15
Total		75	2.7	206
-1952	Jan.	3	3.7	11
	Feb.	5	3.6	18
	Mar.	14	3.1	44
	Apr	24	2.4	58
	May	93	.8	78
	June	128	.9	114
	July	19	1.9	36
	Aug.	12	3.3	40
	Sept.	5	3.8	19
	Oct.	3	4.7	14
	Nov.	4	4.5	18
	Dec.	4	4.0	16
Total		314	1.5	466
-1953	Jan.	6	2.8	17
	Feb.	7	3.1	22
	Mar.	6	3.2	19
	Apr.	3	4.3	13
	May	2	5.5	11
	June	31	1.5	47
	July	5	3.8	19
	Aug.	9	3.7	33
	Sept.	1	5.0	5
	Oct.	4	4.3	17
	Nov.	4	4.5	18
	Dec.	3	4.8	14
Total		81	2.9	235
-1954	Jan.	3	4.0	12
	Feb.	5	3.8	19
	Mar.	4	3.8	15
	Apr.	3	4.3	13
	May	8	2.9	23
	June	1	5.0	5
	July	1	5.0	5
	Aug.	1	3.0	3
	Sept.	4	4.0	16
	Oct.	2	4.0	8
	Nov.	2	4.5	9
	Dec.	2	4.5	9
Total		36	3.8	137
-1955	Jan.	2	4.0	8
	Feb.	2	3.5	7
	Mar.	6	3.5	21
	Apr.	3	3.7	11
	May	4	3.0	12
	June	6	2.8	17
	July	0	0	0
	Aug.	3	3.7	11
	Sept.	0	0	0
	Oct.	0	0	0
	Nov.	1	5.0	5
	Dec.	2	4.5	9
Total		29	3.5	101
-1956	Jan.	3	3.7	11
	Feb.	3	3.3	10
	Mar.	3	3.3	10
	Apr.	1	5.0	5
	May	11	1.6	18
	June	8	2.0	16
	July	1	4.0	4
	Aug.	1	3.0	3
	Sept.	0	0	0
	Oct.	0	0	0
	Nov.	1	5.0	5
	Dec.	1	5.0	5
Total		33	2.6	87
-1957	Jan.	2	3.0	6
	Feb.	4	3.0	12
	Mar.	2	5.0	10
	Apr.	1	5.0	5
	May	9	3.1	28
	June	94	.8	79
	July	24	1.5	37
	Aug.	13	2.8	36
	Sept.	4	3.5	14
	Oct.	10	3.3	33
	Nov.	21	2.5	53
	Dec.	5	3.4	17
Total		189	1.7	330
-1958	Jan.	5	2.6	13
	Feb.	8	2.8	22
	Mar.	6	3.3	20
	Apr.	13	1.6	21
	May	66	.9	60
	June	57	.8	47
	July	2	4.0	8
	Aug.	4	4.5	18
	Sept.	4	4.3	17
	Oct.	1	5.0	5
	Nov.	2	4.0	8
	Dec.	4	3.3	13
Total		172	1.5	252

To obtain mg/l multiply T/AF by 735.

Table 5

Colorado River Basin

Historical Flow and Quality of Water Data

San Rafael River near Green River, Utah

Units - 1000

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
	Jan.	3	3.3	10
	Feb.	4	3.0	12
	Mar.	3	4.0	12
	Apr.	2	3.5	7
	May	1	4.0	4
	June	2	4.0	8
-1959	July	0	0	0
	Aug.	1	3.0	3
	Sept.	1	4.0	4
	Oct.	1	5.0	5
	Nov.	2	4.0	8
	Dec.	1	7.0	7
	Total	21	3.9	81
	Jan.	1	6.0	6
	Feb.	2	3.5	7
	Mar.	8	2.8	22
	Apr.	3	3.3	10
	May	8	1.9	15
	June	11	1.5	17
-1960	July	0	0	0
	Aug.	0	0	0
	Sept.	1	4.0	4
	Oct.	8	2.5	20
	Nov.	2	4.5	9
	Dec.	2	4.0	8
	Total	46	2.6	118
	Jan.	2	3.5	7
	Feb.	3	2.7	8
	Mar.	3	3.5	11
	Apr.	2	4.0	8
	May	3	3.0	9
	June	2	2.5	5
-1961	July	0	0	0
	Aug.	7	2.9	20
	Sept.	18	2.9	53
	Oct.	3	4.0	12
	Nov.	4	3.5	14
	Dec.	2	4.5	9
	Total	50	3.1	156
	Jan.	2	4.0	8
	Feb.	8	2.5	20
	Mar.	6	2.8	17
	Apr.	11	1.3	14
	May	29	1.1	31
	June	37	1.0	37
-1962	July	7	2.6	18
	Aug.	1	4.0	4
	Sept.	3	3.0	9
	Oct.	4	4.5	18
	Nov.	2	5.5	11
	Dec.	2	5.5	11
	Total	112	1.8	198
	Jan.	2	5.5	11
	Feb.	4	3.2	13
	Mar.	2	5.5	11
	Apr.	1	6.0	6
	May	6	2.3	14
	June	10	2.2	22
-1963	July	1	2.0	2
	Aug.	9	3.8	34
	Sept.	6	4.3	26
	Oct.	1	6.0	6
	Nov.	2	4.5	9
	Dec.	2	4.5	9
	Total	46	3.5	163
	Jan.	1	6.0	6
	Feb.	2	4.0	8
	Mar.	3	3.7	11
	Apr.	1	8.0	8
	May	15	1.9	29
	June	20	1.6	33
-1964	July	4	3.8	15
	Aug.	6	3.7	22
	Sept.	1	4.0	4
	Oct.	0	0	0
	Nov.	1	7.0	7
	Dec.	3	4.7	14
	Total	57	2.7	157

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
	Jan.	4	3.5	14
	Feb.	3	3.7	11
	Mar.	3	4.0	12
	Apr.	6	2.7	16
	May	18	1.6	28
	June	77	.9	70
-1965	July	38	1.6	60
	Aug.	16	2.5	40
	Sept.	5	4.0	20
	Oct.	4	4.5	18
	Nov.	5	4.8	24
	Dec.	5	3.2	16
	Total	184	1.8	329
	Jan.	3	3.7	11
	Feb.	3	3.7	11
	Mar.	8	3.5	28
	Apr.	4	3.0	12
	May	4	4.5	18
	June	2	4.0	8
-1966	July	2	4.5	9
	Aug.	1	3.0	3
	Sept.	2	5.0	10
	Oct.	1	8.0	8
	Nov.	1	5.0	5
	Dec.	2	5.0	10
	Total	33	4.0	133
	Jan.	1	4.8	5
	Feb.	2	3.8	8
	Mar.	2	4.6	9
	Apr.	1	5.8	6
	May	5	3.2	16
	June	22	2.0	44
-1967	July	7	2.9	21
	Aug.	3	3.3	10
	Sept.	5	3.6	18
	Oct.	2	4.6	9
	Nov.	2	4.5	9
	Dec.	2	5.0	10
	Total	54	3.1	165
	Jan.	2	5.0	10
	Feb.	3	4.1	12
	Mar.	3	5.2	16
	Apr.	2	4.8	10
	May	6	3.8	23
	June	25	1.3	33
-1968	July	6	3.6	21
	Aug.	11	3.3	36
	Sept.	4	3.9	16
	Oct.	5	4.3	21
	Nov.	3	4.1	12
	Dec.	2	4.7	9
	Total	72	3.0	219
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			

To obtain mg/l multiply T/AF by 735.

Table 5
Colorado River Basin
Historical Flow and Quality of Water Data
San Rafael River near Green River, Utah

(Annual Summary)

Units - 1000

Year	Flow (A.F.)	Concentration (T./A.F.)	Concentration (Mg./l)	T.D.S. (Tons)
1941	139	1.9	1,420	268
1942	137	2.1	1,530	286
1943	73	2.9	2,140	213
1944	149	1.8	1,300	263
1945	85	2.5	1,850	214
1946	69	3.1	2,310	217
1947	111	2.6	1,900	287
1948	62	2.7	1,960	165
1949	135	2.0	1,490	274
1950	53	3.2	2,370	171
1951	75	2.7	2,020	206
1952	314	1.5	1,090	466
1953	81	2.9	2,130	235
1954	36	3.8	2,800	137
1955	29	3.5	2,560	101
1956	33	2.6	1,940	87
1957	189	1.7	1,280	330
1958	172	1.5	1,080	252
1959	21	3.9	2,840	81
1960	46	2.6	1,890	118
1961	48	3.3	2,390	156
1962	112	1.8	1,300	198
1963	46	3.5	2,600	163
1964	57	2.7	2,020	157
1965	184	1.8	1,310	329
1966	33	4.0	2,960	133
1967	54	3.1	2,250	165
1968	72	3.0	2,240	219
Total	2,615			5,891
Average	93	2.3	1,660	210

Sampled quality record November 1946 to September 1949; November 1950 to December 1968; remainder by correlation.

Measured flow record October 1945 to December 1968, remainder by correlation.

Table 6

Colorado River Basin

Historical Flow and Quality of Water Data

Colorado River near Glenwood Springs, Colorado

Units - 1000

Year	Month	Flow (A.F.)	Concen-tration (T./A.F.)	T.D.S. (Tons)
	Jan.	36	0.75	27
	Feb.	37	.59	22
	Mar.	51	.60	30
	Apr.	85	.47	40
	May	535	.22	118
	June	470	.19	90
- 1941	July	163	.37	60
	Aug.	84	.60	50
	Sept.	67	.60	40
	Oct.	78	.58	45
	Nov.	59	.63	37
	Dec.	48	.67	32
	Total	1,713	.34	591
	Jan.	43	.74	32
	Feb.	41	.68	28
	Mar.	46	.70	32
	Apr.	167	.42	70
	May	389	.24	93
	June	721	.16	116
- 1942	July	230	.27	62
	Aug.	78	.53	41
	Sept.	46	.78	36
	Oct.	53	.75	40
	Nov.	49	.76	37
	Dec.	40	.82	33
	Total	1,903	.33	620
	Jan.	37	.86	32
	Feb.	36	.78	28
	Mar.	48	.75	36
	Apr.	162	.34	55
	May	342	.23	79
	June	582	.18	105
- 1943	July	254	.28	71
	Aug.	109	.45	49
	Sept.	66	.64	42
	Oct.	60	.67	40
	Nov.	67	.54	36
	Dec.	64	.53	34
	Total	1,827	.33	607
	Jan.	37	.76	28
	Feb.	44	.66	29
	Mar.	50	.72	36
	Apr.	85	.51	43
	May	302	.26	78
	June	498	.16	80
- 1944	July	185	.29	54
	Aug.	72	.49	35
	Sept.	45	.71	32
	Oct.	60	.65	39
	Nov.	57	.63	36
	Dec.	59	.56	33
	Total	1,494	.35	523
	Jan.	41	.71	29
	Feb.	37	.68	25
	Mar.	62	.50	31
	Apr.	72	.51	37
	May	347	.22	76
	June	461	.18	83
- 1945	July	268	.26	70
	Aug.	181	.33	60
	Sept.	73	.52	38
	Oct.	78	.49	38
	Nov.	73	.47	34
	Dec.	71	.45	32
	Total	1,764	.31	553
	Jan.	67	.48	32
	Feb.	54	.54	29
	Mar.	64	.55	35
	Apr.	197	.28	55
	May	284	.22	62
	June	362	.22	80
- 1946	July	164	.40	65
	Aug.	83	.51	42
	Sept.	59	.66	39
	Oct.	70	.61	43
	Nov.	61	.59	36
	Dec.	77	.40	31
	Total	1,542	.36	549
	Jan.	52	0.60	31
	Feb.	54	.61	33
	Mar.	68	.53	36
	Apr.	123	.37	46
	May	484	.19	92
	June	608	.17	103
- 1947	July	438	.21	92
	Aug.	147	.38	56
	Sept.	79	.53	42
	Oct.	90	.47	42
	Nov.	80	.49	39
	Dec.	75	.48	36
	Total	2,298	.28	648
	Jan.	76	.45	34
	Feb.	72	.44	32
	Mar.	68	.50	34
	Apr.	162	.37	60
	May	542	.20	108
	June	470	.18	85
- 1948	July	156	.35	55
	Aug.	90	.51	46
	Sept.	57	.67	38
	Oct.	63	.65	41
	Nov.	66	.53	35
	Dec.	59	.61	36
	Total	1,881	.32	604
	Jan.	67	.54	36
	Feb.	56	.57	32
	Mar.	58	.59	34
	Apr.	132	.38	50
	May	364	.23	84
	June	654	.19	124
- 1949	July	356	.24	85
	Aug.	106	.45	48
	Sept.	69	.59	41
	Oct.	61	.70	43
	Nov.	55	.71	39
	Dec.	58	.62	36
	Total	2,036	.32	652
	Jan.	56	.63	35
	Feb.	54	.56	30
	Mar.	80	.44	35
	Apr.	141	.35	49
	May	259	.26	67
	June	429	.20	86
- 1950	July	137	.42	58
	Aug.	79	.50	40
	Sept.	66	.58	38
	Oct.	49	.80	39
	Nov.	53	.70	37
	Dec.	55	.61	34
	Total	1,458	.38	548
	Jan.	59	.56	33
	Feb.	58	.52	30
	Mar.	58	.55	32
	Apr.	104	.40	42
	May	381	.23	88
	June	536	.20	107
- 1951	July	285	.25	71
	Aug.	132	.43	57
	Sept.	77	.58	45
	Oct.	75	.61	46
	Nov.	63	.57	36
	Dec.	63	.51	32
	Total	1,891	.33	619
	Jan.	53	.60	32
	Feb.	47	.62	29
	Mar.	63	.51	32
	Apr.	194	.38	74
	May	597	.23	137
	June	785	.19	149
- 1952	July	245	.34	83
	Aug.	157	.51	80
	Sept.	99	.54	53
	Oct.	77	.58	45
	Nov.	66	.64	42
	Dec.	60	.58	35
	Total	2,443	.32	791
	Jan.	64	0.59	38
	Feb.	53	.57	30
	Mar.	67	.54	37
	Apr.	103	.46	47
	May	229	.32	73
	June	509	.20	102
- 1953	July	171	.41	70
	Aug.	121	.50	60
	Sept.	69	.58	40
	Oct.	64	.63	40
	Nov.	55	.75	41
	Dec.	58	.66	38
	Total	1,563	.39	616
	Jan.	62	.58	36
	Feb.	48	.62	30
	Mar.	62	.58	36
	Apr.	86	.44	38
	May	146	.35	51
	June	89	.52	46
- 1954	July	83	.55	46
	Aug.	74	.58	43
	Sept.	59	.61	36
	Oct.	58	.66	38
	Nov.	48	.71	34
	Dec.	40	.90	36
	Total	855	.55	470
	Jan.	38	.79	30
	Feb.	34	.82	28
	Mar.	43	.79	34
	Apr.	90	.48	43
	May	206	.28	58
	June	217	.31	67
- 1955	July	99	.56	56
	Aug.	86	.66	57
	Sept.	67	.57	38
	Oct.	61	.62	38
	Nov.	55	.69	38
	Dec.	55	.60	33
	Total	1,051	.49	520
	Jan.	52	.60	31
	Feb.	48	.56	27
	Mar.	69	.59	41
	Apr.	120	.44	53
	May	421	.26	110
	June	329	.24	79
- 1956	July	104	.54	56
	Aug.	82	.61	50
	Sept.	73	.55	40
	Oct.	66	.55	36
	Nov.	50	.72	36
	Dec.	41	.78	32
	Total	1,455	.41	591
	Jan.	46	.72	33
	Feb.	44	.68	30
	Mar.	51	.67	34
	Apr.	92	.53	49
	May	350	.32	112
	June	834	.21	175
- 1957	July	571	.22	126
	Aug.	176	.37	65
	Sept.	88	.56	49
	Oct.	75	.60	45
	Nov.	72	.58	42
	Dec.	63	.59	37
	Total	2,462	.32	797
	Jan.	62	.55	34
	Feb.	58	.50	29
	Mar.	73	.52	38
	Apr.	102	.45	46
	May	546	.22	120
	June	439	.21	92
- 1958	July	104	.51	53
	Aug.	67	.59	40
	Sept.	62	.58	36
	Oct.	59	.63	37
	Nov.	54	.68	37
	Dec.	54	.63	34
	Total	1,680	.35	596

To obtain mg/l multiply T/AF by 735.

Table 6
Colorado River Basin
Historical Flow and Quality of Water Data
Colorado River near Glenwood Springs, Colorado
Units - 1000

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
- 1959	Jan.	63	0.54	34
	Feb.	54	.52	28
	Mar.	49	.65	32
	Apr.	81	.54	44
	May	252	.29	73
	June	342	.25	85
	July	126	.48	61
	Aug.	89	.61	54
	Sept.	73	.56	41
	Oct.	85	.55	46
	Nov.	69	.55	38
	Dec.	59	.53	31
	Total	1,341	.42	567
- 1960	Jan.	67	.49	33
	Feb.	55	.50	28
	Mar.	93	.47	44
	Apr.	166	.32	53
	May	288	.25	72
	June	357	.25	89
	July	122	.49	60
	Aug.	73	.60	44
	Sept.	67	.60	40
	Oct.	61	.62	38
	Nov.	56	.61	34
	Dec.	61	.54	33
	Total	1,466	.39	568
- 1961	Jan.	65	.52	34
	Feb.	56	.53	30
	Mar.	55	.59	32
	Apr.	66	.54	36
	May	207	.29	60
	June	203	.28	57
	July	82	.60	49
	Aug.	80	.59	47
	Sept.	109	.50	54
	Oct.	128	.43	55
	Nov.	81	.50	40
	Dec.	77	.47	36
	Total	1,209	.44	530
- 1962	Jan.	80	.44	35
	Feb.	91	.42	38
	Mar.	122	.39	48
	Apr.	347	.32	111
	May	539	.23	125
	June	455	.23	105
	July	288	.29	84
	Aug.	110	.50	55
	Sept.	74	.58	43
	Oct.	127	.42	53
	Nov.	102	.47	48
	Dec.	72	.57	41
	Total	2,407	.33	786
- 1963	Jan.	55	.67	37
	Feb.	53	.63	33
	Mar.	62	.58	36
	Apr.	81	.48	39
	May	175	.31	54
	June	122	.45	55
	July	66	.66	44
	Aug.	77	.60	46
	Sept.	76	.57	43
	Oct.	63	.61	38
	Nov.	54	.66	36
	Dec.	38	.82	31
	Total	922	.53	492
- 1964	Jan.	36	.80	29
	Feb.	33	.78	26
	Mar.	39	.71	28
	Apr.	64	.61	39
	May	210	.32	67
	June	215	.31	67
	July	99	.63	62
	Aug.	87	.61	53
	Sept.	72	.60	43
	Oct.	65	.64	42
	Nov.	50	.72	36
	Dec.	51	.73	37
	Total	1,021	.52	529
- 1965	Jan.	51	0.70	36
	Feb.	44	.73	32
	Mar.	49	.69	34
	Apr.	104	.50	52
	May	263	.30	79
	June	446	.26	116
	July	271	.31	84
	Aug.	172	.39	67
	Sept.	95	.50	48
	Oct.	95	.44	42
	Nov.	86	.46	39
	Dec.	88	.47	41
	Total	1,764	.38	670
- 1966	Jan.	78	0.48	37
	Feb.	70	.46	32
	Mar.	91	.46	42
	Apr.	84	.47	39
	May	186	.30	56
	June	110	.45	50
	July	89	.51	45
	Aug.	77	.46	35
	Sept.	68	.51	35
	Oct.	72	.60	43
	Nov.	55	.66	36
	Dec.	44	.75	33
	Total	1,024	.47	483
- 1967	Jan.	49	.65	32
	Feb.	45	.62	28
	Mar.	67	.59	40
	Apr.	96	.45	43
	May	185	.31	57
	June	250	.28	70
	July	139	.47	65
	Aug.	90	.57	51
	Sept.	83	.59	49
	Oct.	78	.59	46
	Nov.	69	.57	39
	Dec.	59	.59	35
	Total	1,210	.46	555
- 1968	Jan.	53	.61	32
	Feb.	53	.55	29
	Mar.	62	.55	34
	Apr.	95	.46	44
	May	171	.36	62
	June	369	.25	92
	July	133	.46	61
	Aug.	125	.48	60
	Sept.	79	.53	42
	Oct.	77	.55	42
	Nov.	68	.54	37
	Dec.	65	.59	38
	Total	1,350	.42	573
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			
	Jan.			
	Feb.			
	Mar.			
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	Dec.			
	Total			
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	Total			
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	Total			
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	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			
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	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			

To obtain mg/l multiply T/AF by 735.

Table 6
Colorado River Basin
Historical Flow and Quality of Water Data
Colorado River near Glenwood Springs, Colorado

(Annual Summary)

Units - 1000

Year	Flow (A.F.)	Concentration (T./A.F.)	Concentration (Mg./l)	T.D.S. (Tons)
1941	1,713	0.34	254	591
1942	1,903	.33	239	620
1943	1,827	.33	244	607
1944	1,494	.35	257	523
1945	1,764	.31	230	553
1946	1,542	.36	262	549
1947	2,298	.28	207	648
1948	1,881	.32	236	604
1949	2,036	.32	235	652
1950	1,458	.38	276	548
1951	1,891	.33	241	619
1952	2,443	.32	238	791
1953	1,563	.39	290	616
1954	855	.55	404	470
1955	1,051	.49	364	520
1956	1,455	.41	299	591
1957	2,462	.32	238	797
1958	1,680	.35	261	596
1959	1,341	.42	311	567
1960	1,466	.39	285	568
1961	1,209	.44	322	530
1962	2,407	.33	240	786
1963	922	.53	392	492
1964	1,021	.52	381	529
1965	1,764	.38	279	670
1966	1,024	.47	347	483
1967	1,210	.46	337	555
1968	1,350	.42	312	573
Total	45,030			16,648
Average	1,608	.37	272	595

Sampled quality record October 1941 to December 1968; remainder by correlation.

Measured flow record entire period.

Table 7

Colorado River Basin

Historical Flow and Quality of Water Data

Colorado River near Cameo, Colorado

Units - 1000

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
	Jan.	65	1.23	80
	Feb.	67	1.15	77
	Mar.	82	1.11	91
	Apr.	133	.83	110
	May	948	.34	322
	June	803	.28	225
-1941	July	315	.47	148
	Aug.	144	.91	131
	Sept.	122	.97	118
	Oct.	166	.88	146
	Nov.	124	.96	119
	Dec.	103	1.11	114
Total		3,072	.55	1,681
	Jan.	90	1.24	112
	Feb.	86	1.19	102
	Mar.	103	1.13	116
	Apr.	334	.62	207
	May	757	.41	310
	June	1,215	.24	292
-1942	July	406	.44	179
	Aug.	139	.85	118
	Sept.	86	1.15	99
	Oct.	94	1.18	111
	Nov.	94	1.24	117
	Dec.	84	1.26	106
Total		3,488	.54	1,869
	Jan.	77	1.30	100
	Feb.	74	1.26	93
	Mar.	89	1.22	109
	Apr.	237	.56	133
	May	509	.32	163
	June	931	.23	214
-1943	July	387	.39	151
	Aug.	192	.73	140
	Sept.	117	.89	104
	Oct.	111	1.00	111
	Nov.	115	.90	103
	Dec.	107	.93	100
Total		2,946	.52	1,521
	Jan.	74	1.24	92
	Feb.	76	1.11	84
	Mar.	81	1.11	90
	Apr.	118	.85	100
	May	564	.36	203
	June	890	.24	214
-1944	July	378	.38	143
	Aug.	123	.80	98
	Sept.	78	1.09	85
	Oct.	99	1.05	104
	Nov.	100	1.01	101
	Dec.	99	1.02	101
Total		2,680	.53	1,415
	Jan.	78	1.15	90
	Feb.	72	1.18	85
	Mar.	95	.99	94
	Apr.	115	.90	104
	May	601	.36	216
	June	734	.27	214
-1945	July	499	.33	165
	Aug.	287	.52	149
	Sept.	118	.83	98
	Oct.	126	.79	100
	Nov.	125	.81	101
	Dec.	117	.89	104
Total		3,027	.50	1,520
	Jan.	109	.90	98
	Feb.	91	.97	88
	Mar.	99	.94	93
	Apr.	285	.45	128
	May	449	.32	144
	June	689	.28	193
-1946	July	267	.51	136
	Aug.	126	.85	107
	Sept.	92	1.01	93
	Oct.	122	.89	109
	Nov.	104	.92	96
	Dec.	121	.82	99
Total		2,554	.54	1,384
	Jan.	82	1.04	85
	Feb.	82	.99	81
	Mar.	107	.96	103
	Apr.	178	.63	112
	May	809	.28	227
	June	1,027	.25	257
-1947	July	732	.27	198
	Aug.	240	.58	139
	Sept.	143	.78	111
	Oct.	153	.80	122
	Nov.	135	.77	104
	Dec.	118	.86	102
Total		3,806	.43	1,641
	Jan.	116	.84	97
	Feb.	111	.81	90
	Mar.	115	.90	104
	Apr.	253	.59	149
	May	920	.30	276
	June	844	.26	219
-1948	July	312	.47	146
	Aug.	161	.77	124
	Sept.	88	1.03	91
	Oct.	109	1.02	111
	Nov.	107	.96	103
	Dec.	90	1.04	94
Total		3,226	.50	1,604
	Jan.	99	.96	95
	Feb.	84	.92	77
	Mar.	98	.98	96
	Apr.	201	.65	131
	May	572	.36	206
	June	1,080	.26	281
-1949	July	594	.34	202
	Aug.	184	.69	127
	Sept.	122	.93	113
	Oct.	125	.98	123
	Nov.	108	1.01	109
	Dec.	101	1.05	106
Total		3,368	.49	1,666
	Jan.	91	1.04	95
	Feb.	88	.95	84
	Mar.	118	.87	103
	Apr.	212	.59	125
	May	418	.40	167
	June	787	.27	212
-1950	July	273	.54	147
	Aug.	125	.87	109
	Sept.	111	.97	108
	Oct.	97	1.19	115
	Nov.	98	1.14	112
	Dec.	98	1.07	105
Total		2,516	.59	1,482
	Jan.	96	1.01	97
	Feb.	88	.95	84
	Mar.	99	1.01	100
	Apr.	151	.70	106
	May	537	.34	183
	June	858	.27	232
-1951	July	471	.36	170
	Aug.	207	.68	141
	Sept.	111	.90	100
	Oct.	120	.92	110
	Nov.	106	.97	101
	Dec.	106	.96	102
Total		2,948	.52	1,526
	Jan.	96	1.01	97
	Feb.	84	1.06	89
	Mar.	113	.99	112
	Apr.	313	.60	188
	May	978	.36	352
	June	1,320	.26	343
-1952	July	449	.44	197
	Aug.	276	.70	193
	Sept.	171	.78	133
	Oct.	123	.97	119
	Nov.	112	1.04	117
	Dec.	99	1.12	111
Total		4,134	.50	2,051
	Jan.	99	1.03	102
	Feb.	80	1.06	85
	Mar.	102	.96	98
	Apr.	136	.78	106
	May	346	.44	152
	June	887	.27	239
-1953	July	294	.52	153
	Aug.	194	.72	140
	Sept.	101	.99	100
	Oct.	101	1.06	107
	Nov.	99	1.13	112
	Dec.	92	1.17	108
Total		2,531	.59	1,502
	Jan.	95	1.00	95
	Feb.	81	1.05	85
	Mar.	94	1.01	95
	Apr.	136	.78	106
	May	296	.48	142
	June	204	.60	123
-1954	July	146	.81	118
	Aug.	105	.97	102
	Sept.	103	1.07	110
	Oct.	125	.97	121
	Nov.	98	1.07	105
	Dec.	82	1.23	101
Total		1,565	.83	1,303
	Jan.	74	1.23	91
	Feb.	67	1.25	84
	Mar.	86	1.13	97
	Apr.	142	.77	110
	May	384	.42	161
	June	448	.37	166
-1955	July	214	.61	130
	Aug.	157	.87	137
	Sept.	100	.94	94
	Oct.	91	1.02	93
	Nov.	94	1.06	100
	Dec.	89	1.07	95
Total		1,946	.70	1,358
	Jan.	81	1.07	87
	Feb.	75	1.11	83
	Mar.	104	.98	102
	Apr.	184	.66	122
	May	685	.34	233
	June	637	.31	197
-1956	July	173	.70	121
	Aug.	115	.95	109
	Sept.	88	.90	79
	Oct.	93	.95	88
	Nov.	83	1.07	89
	Dec.	73	1.21	88
Total		2,391	.59	1,398
	Jan.	80	1.10	88
	Feb.	77	1.10	85
	Mar.	83	1.16	96
	Apr.	151	.83	125
	May	591	.47	278
	June	1,415	.27	382
-1957	July	1,072	.27	289
	Aug.	339	.50	170
	Sept.	157	.78	122
	Oct.	136	.89	121
	Nov.	123	.91	112
	Dec.	102	.96	98
Total		4,326	.45	1,966
	Jan.	92	.93	86
	Feb.	95	.93	88
	Mar.	123	.89	110
	Apr.	171	.76	130
	May	847	.31	263
	June	808	.27	218
-1958	July	193	.67	129
	Aug.	109	.97	106
	Sept.	103	1.03	106
	Oct.	99	1.09	108
	Nov.	94	1.09	102
	Dec.	86	1.12	96
Total		2,820	.55	1,542

To obtain mg/l multiply T/AF by 735

Table 7

Colorado River Basin

Historical Flow and Quality of Water Data

Colorado River near Cameo, Colorado

Units - 1000

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)	Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)	Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
-1959	Jan.	94	1.02	96	-1965	Jan.	92	1.10	101		Jan.			
	Feb.	86	1.01	87		Feb.	78	1.09	85		Feb.			
	Mar.	83	1.09	90		Mar.	85	1.15	98		Mar.			
	Apr.	118	.83	98		Apr.	161	.69	111		Apr.			
	May	392	.40	157		May	477	.39	186		May			
	June	686	.29	198		June	920	.28	258		June			
	July	215	.59	127		July	605	.34	206		July			
	Aug.	131	.87	114		Aug.	273	.56	153		Aug.			
	Sept.	105	.98	103		Sept.	172	.75	129		Sept.			
	Oct.	138	.81	112		Oct.	167	.75	125		Oct.			
	Nov.	116	.87	101		Nov.	137	.75	103		Nov.			
	Dec.	100	.98	98		Dec.	138	.75	103		Dec.			
Total		2,262	.61	1,381	Total		3,305	.50	1,658	Total				
-1960	Jan.	100	.89	89	-1966	Jan.	114	.82	93		Jan.			
	Feb.	91	.95	86		Feb.	99	.81	80		Feb.			
	Mar.	135	.78	105		Mar.	133	.77	102		Mar.			
	Apr.	246	.51	125		Apr.	141	.66	93		Apr.			
	May	432	.37	160		May	373	.40	149		May			
	June	668	.30	200		June	277	.48	133		June			
	July	217	.60	130		July	157	.73	115		July			
	Aug.	117	.89	104		Aug.	119	.87	104		Aug.			
	Sept	102	.95	97		Sept.	101	.94	95		Sept.			
	Oct.	106	1.00	106		Oct.	108	.98	106		Oct.			
	Nov.	99	1.05	104		Nov.	93	1.05	98		Nov.			
	Dec.	100	1.01	101		Dec.	85	1.22	104		Dec.			
Total		2,413	.58	1,407	Total		1,800	.71	1,272	Total				
-1961	Jan.	99	.97	96	-1967	Jan.	86	1.11	95		Jan.			
	Feb.	85	.94	80		Feb.	74	1.06	78		Feb.			
	Mar.	86	1.06	91		Mar.	106	.93	99		Mar.			
	Apr.	103	.91	94		Apr.	137	.72	99		Apr.			
	May	354	.40	142		May	328	.43	141		May			
	June	426	.34	145		June	543	.31	168		June			
	July	138	.81	112		July	289	.53	153		July			
	Aug.	115	.89	102		Aug.	137	.83	114		Aug.			
	Sept.	175	.73	128		Sept.	125	.90	112		Sept.			
	Oct.	200	.59	118		Oct.	115	.92	106		Oct.			
	Nov.	131	.73	96		Nov.	104	.95	99		Nov.			
	Dec.	121	.78	94		Dec.	100	1.00	100		Dec.			
Total		2,033	.64	1,298	Total		2,144	.64	1,364	Total				
-1962	Jan.	115	.78	90	-1968	Jan.	89	1.12	100		Jan.			
	Feb.	135	.74	100		Feb.	87	.98	85		Feb.			
	Mar.	160	.69	110		Mar.	96	1.01	97		Mar.			
	Apr.	513	.40	205		Apr.	133	.77	102		Apr.			
	May	892	.31	277		May	326	.43	140		May			
	June	882	.27	238		June	757	.27	204		June			
	July	545	.37	202		July	257	.57	146		July			
	Aug.	186	.72	134		Aug.	224	.67	150		Aug.			
	Sept.	121	.95	115		Sept.	125	.86	108		Sept.			
	Oct.	173	.74	128		Oct.	128	.91	116		Oct.			
	Nov.	148	.79	117		Nov.	113	.95	107		Nov.			
	Dec.	115	.99	114		Dec.	106	.99	103		Dec.			
Total		3,985	.66	1,830	Total		2,439	.60	1,458	Total				
-1963	Jan.	95	1.11	105		Jan.					Jan.			
	Feb.	87	.98	85		Feb.					Feb.			
	Mar.	98	1.02	100		Mar.					Mar.			
	Apr.	127	.79	100		Apr.					Apr.			
	May	323	.40	129		May					May			
	June	246	.53	130		June					June			
	July	111	.91	101		July					July			
	Aug.	115	.92	106		Aug.					Aug.			
	Sept.	112	.89	100		Sept.					Sept.			
	Oct.	96	.99	95		Oct.					Oct.			
	Nov.	90	1.09	98		Nov.					Nov.			
	Dec.	71	1.32	94		Dec.					Dec.			
Total		1,571	.79	1,263	Total					Total				
-1964	Jan.	58	1.29	75		Jan.					Jan.			
	Feb.	55	1.19	65		Feb.					Feb.			
	Mar.	67	1.13	76		Mar.					Mar.			
	Apr.	105	.92	97		Apr.					Apr.			
	May	403	.41	165		May					May			
	June	465	.35	163		June					June			
	July	223	.62	138		July					July			
	Aug.	153	.81	124		Aug.					Aug.			
	Sept.	116	.86	100		Sept.					Sept.			
	Oct.	104	1.01	105		Oct.					Oct.			
	Nov.	96	1.11	104		Nov.					Nov.			
	Dec.	91	1.08	98		Dec.					Dec.			
Total		1,934	.68	1,310	Total					Total				

To obtain mg/l multiply T/AF by 735.

Table 7

Colorado River Basin

Historical Flow and Quality of Water Data

Colorado River near Cameo, Colorado

(Annual Summary)

Units - 1000

Year	Flow	Concentration		T.D.S.
	(A.F.)	(T./A.F.)	(Mg./l)	(Tons)
1941	3,072	0.55	402	1,681
1942	3,489	.54	394	1,869
1943	2,946	.52	379	1,521
1944	2,680	.53	388	1,415
1945	3,027	.50	369	1,520
1946	2,554	.54	398	1,384
1947	3,806	.43	317	1,641
1948	3,226	.50	365	1,604
1949	3,368	.49	364	1,666
1950	2,516	.59	433	1,482
1951	2,948	.52	380	1,526
1952	4,134	.50	365	2,051
1953	2,531	.59	436	1,502
1954	1,565	.83	612	1,303
1955	1,946	.70	513	1,358
1956	2,391	.59	430	1,398
1957	4,326	.45	334	1,966
1958	2,820	.55	402	1,542
1959	2,262	.61	449	1,381
1960	2,413	.58	429	1,407
1961	2,033	.64	469	1,298
1962	3,985	.46	338	1,830
1963	1,571	.79	582	1,243
1964	1,934	.68	498	1,310
1965	3,035	.50	369	1,658
1966	1,800	.71	519	1,272
1967	2,144	.64	468	1,364
1968	2,439	.60	439	1,458
Total	77,229			42,651
Average	2,758	.55	406	1,523

Sampled quality record entire period.
Measured flow record entire period.

Table 8

Colorado River Basin

Historical Flow and Quality of Water Data

Gunnison River near Grand Junction, Colorado

Units - 1000

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
-1941	Jan.	51	1.90	97
	Feb.	51	1.82	93
	Mar.	63	1.67	105
	Apr.	123	1.00	123
	May	871	.40	349
	June	563	.46	259
	July	192	.94	180
	Aug.	95	1.41	134
	Sept.	81	2.11	171
	Oct.	198	1.35	[illegible]
	Nov.	121	1.33	161
	Dec.	84	1.58	133
Total		2,493	.83	2,072
-1942	Jan.	71	1.59	113
	Feb.	62	1.66	103
	Mar.	76	1.64	125
	Apr.	546	.52	284
	May	760	.47	357
	June	688	.38	261
	July	167	.93	156
	Aug.	68	2.18	148
	Sept.	56	2.36	132
	Oct.	57	2.58	147
	Nov.	65	1.92	125
	Dec.	58	1.83	106
Total		2,674	.77	2,057
-1943	Jan.	57	1.72	98
	Feb.	48	1.60	77
	Mar.	56	1.55	87
	Apr.	279	.44	123
	May	389	.48	187
	June	397	.46	183
	July	113	1.08	122
	Aug.	153	1.43	219
	Sept.	87	1.59	138
	Oct.	69	1.84	127
	Nov.	75	1.59	119
	Dec.	61	1.57	96
Total		1,784	.88	1,574
-1944	Jan.	51	1.65	84
	Feb.	48	1.44	69
	Mar.	53	1.42	75
	Apr.	102	.97	99
	May	758	.32	242
	June	694	.33	229
	July	230	.69	159
	Aug.	51	1.94	99
	Sept.	45	2.44	110
	Oct.	58	2.31	134
	Nov.	71	1.86	132
	Dec.	64	1.73	111
Total		2,225	.69	1,541
-1945	Jan.	55	1.58	87
	Feb.	47	1.62	76
	Mar.	52	1.48	77
	Apr.	91	1.00	91
	May	628	.35	220
	June	407	.46	187
	July	163	.85	139
	Aug.	122	1.22	149
	Sept.	46	2.39	110
	Oct.	76	2.00	152
	Nov.	73	1.63	119
	Dec.	58	1.59	[illegible]
Total		1,818	.82	1,499
-1946	Jan.	58	1.55	90
	Feb.	48	1.44	69
	Mar.	58	1.28	74
	Apr.	182	.59	108
	May	229	.59	135
	June	321	.52	167
	July	64	1.62	104
	Aug.	56	2.16	121
	Sept.	54	2.31	125
	Oct.	69	2.06	142
	Nov.	67	1.70	114
	Dec.	56	1.55	87
Total		1,262	1.06	1,336

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
-1947	Jan.	45	1.67	75
	Feb.	47	1.49	70
	Mar.	55	1.27	70
	Apr.	96	.82	79
	May	455	.39	177
	June	502	.46	231
	July	242	.64	155
	Aug.	120	1.50	180
	Sept.	96	1.63	156
	Oct.	114	1.60	183
	Nov.	96	1.35	130
	Dec.	70	1.41	99
Total		1,938	.83	1,605
-1948	Jan.	58	1.38	80
	Feb.	65	1.43	93
	Mar.	76	1.38	105
	Apr.	324	.51	165
	May	835	.30	251
	June	546	.40	218
	July	141	.92	129
	Aug.	71	1.84	131
	Sept.	48	2.25	108
	Oct.	57	2.09	119
	Nov.	70	1.84	129
	Dec.	70	1.64	115
Total		2,361	.70	1,643
-1949	Jan.	51	1.49	76
	Feb.	52	1.48	77
	Mar.	69	1.42	98
	Apr.	236	.57	134
	May	481	.38	183
	June	651	.42	273
	July	265	.65	172
	Aug.	65	1.80	117
	Sept.	53	2.15	114
	Oct.	70	2.09	146
	Nov.	74	1.58	117
	Dec.	54	1.74	94
Total		2,121	.76	1,601
-1950	Jan.	54	1.57	85
	Feb.	57	2.00	114
	Mar.	60	1.33	80
	Apr.	219	.50	110
	May	309	.45	139
	June	319	.50	160
	July	88	1.43	126
	Aug.	37	2.16	80
	Sept.	46	2.61	120
	Oct.	37	2.65	98
	Nov.	49	2.12	104
	Dec.	60	1.73	104
Total		1,335	.99	1,324
-1951	Jan.	47	1.64	77
	Feb.	46	1.59	73
	Mar.	55	1.27	70
	Apr.	62	.97	60
	May	265	.51	135
	June	323	.52	168
	July	93	1.06	99
	Aug.	53	1.72	91
	Sept.	37	2.30	85
	Oct.	49	2.41	118
	Nov.	60	1.88	113
	Dec.	46	1.65	76
Total		1,136	1.03	1,165
-1952	Jan.	53	1.53	81
	Feb.	47	1.48	70
	Mar.	53	1.41	75
	Apr.	342	.46	157
	May	818	.33	270
	June	759	.35	266
	July	200	.79	158
	Aug.	121	1.54	187
	Sept.	76	1.86	141
	Oct.	67	1.90	127
	Nov.	64	2.00	128
	Dec.	72	1.68	121
Total		2,672	.67	1,781

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
-1953	Jan.	65	1.51	98
	Feb.	50	1.48	74
	Mar.	61	1.26	77
	Apr.	86	1.01	87
	May	230	.57	131
	June	437	.43	188
	July	86	1.13	97
	Aug.	67	1.75	117
	Sept.	46	2.28	105
	Oct.	58	2.40	139
	Nov.	74	1.78	132
	Dec.	52	1.83	95
Total		1,312	1.02	1,340
-1954	Jan.	49	1.75	86
	Feb.	45	1.58	71
	Mar.	45	1.49	67
	Apr.	70	.84	59
	May	110	.85	93
	June	39	1.92	75
	July	40	2.10	84
	Aug.	31	2.64	82
	Sept.	52	2.50	130
	Oct.	64	1.94	124
	Nov.	51	1.92	98
	Dec.	49	1.90	93
Total		645	1.65	1,062
-1955	Jan.	46	1.70	78
	Feb.	40	1.67	67
	Mar.	59	1.47	87
	Apr.	108	.74	80
	May	262	.52	136
	June	219	.63	138
	July	46	1.74	80
	Aug.	52	1.86	97
	Sept.	36	2.48	89
	Oct.	38	2.47	94
	Nov.	54	2.08	112
	Dec.	57	1.65	94
Total		1,017	1.13	1,152
-1956	Jan.	50	1.64	82
	Feb.	44	1.59	70
	Mar.	56	1.30	73
	Apr.	142	.60	85
	May	324	.45	146
	June	262	.53	139
	July	37	1.92	71
	Aug.	29	2.07	60
	Sept.	20	3.15	63
	Oct.	35	2.94	103
	Nov.	55	1.95	107
	Dec.	47	1.87	88
Total		1,101	.99	1,087
-195	Jan.	52	1.73	90
	Feb.	55	1.69	93
	Mar.	56	1.36	76
	Apr.	136	.67	91
	May	554	.44	244
	June	1,168	.32	374
	July	719	.39	281
	Aug.	224	.83	186
	Sept.	108	1.47	159
	Oct.	106	1.92	204
	Nov.	111	1.33	148
	Dec.	92	1.26	116
Total		3,381	.61	2,062
--195	Jan.	66	1.40	92
	Feb.	70	1.50	105
	Mar.	82	1.24	102
	Apr.	254	.57	145
	May	873	.32	279
	June	570	.42	239
	July	65	1.52	99
	Aug.	43	1.74	75
	Sept.	51	2.31	118
	Oct.	52	2.42	126
	Nov.	71	1.82	129
	Dec.	65	1.60	104
Total		2,262	.71	1,613

To obtain mg/l multiply T/AF by 735.

Table 8

Colorado River Basin

Historical Flow and Quality of Water Data

Gunnison River near Grand Junction, Colorado

Units-1000

Year	Month	Flow (A.F.)	Concen-tration (T./A.F.)	T.D.S. (Tons)
	Jan.	57	1.58	90
	Feb.	50	1.51	75
	Mar.	52	1.34	70
	Apr.	55	1.10	61
	May	167	.75	125
	June	256	.66	169
-1959	July	34	2.39	81
	Aug.	51	2.01	103
	Sept.	41	2.46	101
	Oct.	96	1.45	139
	Nov.	72	1.39	100
	Dec.	50	1.54	77
	Total	981	1.21	1,191
	Jan.	49	1.46	72
	Feb.	41	1.48	61
	Mar.	87	1.26	110
	Apr.	270	.45	122
	May	259	.45	117
	June	336	.46	155
-1960	July	58	1.33	77
	Aug.	34	2.08	71
	Sept.	38	2.22	84
	Oct.	51	2.34	119
	Nov.	58	1.69	98
	Dec.	51	1.59	81
	Total	1,332	.88	1,167
	Jan.	41	1.66	68
	Feb.	40	1.55	62
	Mar.	55	1.29	71
	Apr.	67	1.05	70
	May	266	.50	133
	June	209	.62	130
-1961	July	34	2.09	71
	Aug.	44	2.07	91
	Sept.	100	1.66	166
	Oct.	107	1.20	128
	Nov.	86	1.20	103
	Dec.	57	1.37	78
	Total	1,106	1.06	1,171
	Jan.	52	1.37	71
	Feb.	58	1.35	78
	Mar.	53	1.22	65
	Apr.	395	.37	146
	May	574	.32	184
	June	477	.37	176
-1962	July	219	.67	147
	Aug.	52	1.72	89
	Sept.	63	1.97	124
	Oct.	70	1.84	129
	Nov.	68	1.62	110
	Dec.	54	1.70	92
	Total	2,135	.66	1,411
	Jan.	48	1.66	80
	Feb.	70	1.51	105
	Mar.	82	1.11	91
	Apr.	102	.72	73
	May	188	.53	100
	June	92	1.02	95
-1963	July	37	2.11	78
	Aug.	52	1.99	104
	Sept.	51	2.28	116
	Oct.	55	2.52	139
	Nov.	66	1.70	112
	Dec.	49	1.69	83
	Total	892	1.32	1,176
	Jan.	43	1.58	68
	Feb.	45	1.51	68
	Mar.	43	1.52	65
	Apr.	78	1.00	78
	May	418	.41	171
	June	316	.50	158
-1964	July	83	1.20	100
	Aug.	93	1.61	150
	Sept.	59	1.99	117
	Oct.	53	2.20	117
	Nov.	65	1.85	120
	Dec.	59	1.46	86
	Total	1,355	.96	1,298
	Jan.	55	1.37	75
	Feb.	45	1.28	58
	Mar.	52	1.33	69
	Apr.	228	.52	119
	May	582	.36	210
	June	681	.37	252
-1965	July	472	.47	222
	Aug.	158	.98	155
	Sept.	161	1.29	208
	Oct.	116	1.35	157
	Nov.	63	1.93	122
	Dec.	60	1.58	95
	Total	2,673	.65	1,742
	Jan.	52	1.67	87
	Feb.	37	1.86	69
	Mar.	68	1.30	88
	Apr.	166	.65	108
	May	211	.67	141
	June	125	1.03	129
-1966	July	51	1.75	89
	Aug.	38	2.09	79
	Sept.	58	1.99	115
	Oct.	65	2.03	132
	Nov.	45	2.34	105
	Dec.	55	1.76	97
	Total	971	1.28	1,239
	Jan.	47	1.63	77
	Feb.	42	1.62	68
	Mar.	62	1.16	72
	Apr.	86	.73	63
	May	143	.81	116
	June	152	1.03	157
-1967	July	60	1.78	107
	Aug.	59	1.93	114
	Sept.	70	1.88	132
	Oct.	65	1.88	122
	Nov.	106	1.16	123
	Dec.	165	.73	120
	Total	1,057	1.20	1,271
	Jan.	119	.95	113
	Feb.	96	1.03	99
	Mar.	65	1.20	78
	Apr.	68	.97	66
	May	268	.57	153
	June	258	.56	144
-1968	July	59	1.62	96
	Aug.	107	1.56	167
	Sept.	68	1.86	126
	Oct.	87	1.72	150
	Nov.	133	1.08	144
	Dec.	149	.77	115
	Total	1,477	.98	1,451
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			
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	Apr.			
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	Nov.			
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	Total			
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	Dec.			
	Total			
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			

To obtain mg/l multiply T/AF by 735.

Table 8

Colorado River Basin

Historical Flow and Quality of Water Data

Gunnison River near Grand Junction, Colorado

(Annual Summary)

Units - 1000

Year	Flow (A.F.)	Concentration (T./A.F.)	Concentration (Mg./l)	T.D.S. (Tons)
1941	2,493	.83	611	2,072
1942	2,674	.77	565	2,057
1943	1,784	.88	649	1,576
1944	2,225	.69	510	1,543
1945	1,818	.82	606	1,499
1946	1,262	1.06	778	1,336
1947	1,938	.83	609	1,605
1948	2,361	.70	511	1,643
1949	2,121	.76	555	1,601
1950	1,335	.99	727	1,320
1951	1,136	1.03	754	1,165
1952	2,672	.67	490	1,781
1953	1,312	1.02	751	1,340
1954	645	1.65	1,210	1,062
1955	1,017	1.13	833	1,152
1956	1,101	.99	726	1,087
1957	3,381	.61	448	2,062
1958	2,262	.71	524	1,613
1959	981	1.21	892	1,191
1960	1,332	.88	644	1,167
1961	1,106	1.06	778	1,171
1962	2,135	.66	486	1,411
1963	892	1.32	969	1,176
1964	1,355	.96	704	1,298
1965	2,673	.65	479	1,742
1966	971	1.28	938	1,239
1967	1,057	1.20	884	1,271
1968	1,477	.98	722	1,451
Total	47,516			40,631
Average	1,697	.86	628	1,451

Sampled quality record entire period.
Measured flow record entire period.

Table 9

Colorado River Basin

Historical Flow and Quality of Water Data

Colorado River near Cisco, Utah

Units - 1000

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
	Jan.	139	1.86	259
	Feb.	153	1.78	272
	Mar.	207	1.64	339
	Apr.	445	1.00	445
	May	2,355	.42	989
	June	1,582	.46	728
- 1941	July	579	.73	423
	Aug.	251	1.67	419
	Sept.	237	1.81	429
	Oct.	579	1.10	637
	Nov.	311	1.18	367
	Dec.	229	1.51	346
	Total	7,067	.80	5,653
	Jan.	181	1.67	302
	Feb.	165	1.73	285
	Mar.	228	1.52	347
	Apr.	1,344	.61	820
	May	1,809	.45	814
	June	1,961	.37	725
- 1942	July	579	.78	451
	Aug.	185	1.84	340
	Sept.	134	2.46	329
	Oct.	162	2.33	378
	Nov.	186	1.99	370
	Dec.	164	1.96	322
	Total	7,098	.77	5,483
	Jan.	153	1.90	291
	Feb.	146	1.85	270
	Mar.	174	1.77	308
	Apr.	709	.64	454
	May	996	.46	458
	June	1,365	.38	518
- 1943	July	502	.78	392
	Aug.	368	1.26	463
	Sept.	212	1.85	392
	Oct.	184	1.84	339
	Nov.	215	1.47	317
	Dec.	190	1.56	296
	Total	5,214	.86	4,498
	Jan.	140	1.77	248
	Feb.	152	1.56	237
	Mar.	166	1.51	251
	Apr.	304	1.09	331
	May	1,784	.41	732
	June	1,843	.35	645
- 1944	July	677	.61	413
	Aug.	149	1.62	241
	Sept.	99	2.54	252
	Oct.	159	2.18	347
	Nov.	196	1.78	348
	Dec.	171	1.70	291
	Total	5,840	.74	4,336
	Jan.	149	1.73	258
	Feb.	151	1.74	263
	Mar.	178	1.56	277
	Apr.	328	.88	289
	May	1,495	.36	538
	June	1,311	.37	485
- 1945	July	676	.67	453
	Aug.	446	1.01	451
	Sept.	146	1.85	270
	Oct.	217	1.75	380
	Nov.	224	1.41	316
	Dec.	183	1.26	230
	Total	5,504	.76	4,210
	Jan.	174	1.37	239
	Feb.	155	1.27	197
	Mar.	191	1.24	236
	Apr.	525	.61	320
	May	726	.49	356
	June	1,027	.42	432
- 1946	July	309	.98	303
	Aug.	196	1.66	325
	Sept.	135	2.10	283
	Oct.	206	1.85	382
	Nov.	206	1.56	322
	Dec.	208	1.37	285
	Total	4,058	.91	3,680

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
	Jan.	145	1.58	229
	Feb.	150	1.44	216
	Mar.	189	1.39	263
	Apr.	316	.85	268
	May	1,423	.40	569
	June	1,594	.39	621
- 1947	July	985	.47	463
	Aug.	369	1.21	447
	Sept.	259	1.44	373
	Oct.	328	1.47	482
	Nov.	277	1.24	343
	Dec.	223	1.40	312
	Total	6,258	.73	4,587
	Jan.	191	1.34	256
	Feb.	210	1.33	280
	Mar.	245	1.36	333
	Apr.	830	.64	531
	May	1,959	.36	705
	June	1,499	.39	585
- 1948	July	446	.86	384
	Aug.	225	1.52	342
	Sept.	121	1.88	228
	Oct.	175	1.96	343
	Nov.	204	1.67	341
	Dec.	186	1.66	308
	Total	6,291	.74	4,636
	Jan.	188	1.54	289
	Feb.	187	1.35	253
	Mar.	243	1.40	340
	Apr.	615	.67	412
	May	1,289	.41	529
	June	1,910	.37	707
- 1949	July	908	.55	499
	Aug.	224	1.58	354
	Sept.	158	2.08	328
	Oct.	226	1.83	414
	Nov.	210	1.71	359
	Dec.	180	1.66	299
	Total	6,338	.75	4,783
	Jan.	199	1.52	302
	Feb.	201	1.44	289
	Mar.	209	1.31	274
	Apr.	541	.61	330
	May	764	.51	389
	June	1,113	.42	467
- 1950	July	347	1.03	357
	Aug.	109	2.02	220
	Sept.	138	2.12	292
	Oct.	125	2.35	294
	Nov.	161	1.96	316
	Dec.	167	1.75	293
	Total	4,074	.94	3,823
	Jan.	153	1.69	258
	Feb.	151	1.51	228
	Mar.	161	1.46	236
	Apr.	173	1.21	209
	May	758	.54	409
	June	1,173	.43	505
- 1951	July	529	.68	360
	Aug.	238	1.47	350
	Sept.	131	2.06	270
	Oct.	169	1.99	336
	Nov.	178	1.74	310
	Dec.	172	1.67	287
	Total	3,986	.94	3,758
	Jan.	191	1.59	303
	Feb.	155	1.65	256
	Mar.	194	1.48	287
	Apr.	969	.53	514
	May	2,152	.35	753
	June	2,314	.33	764
- 1952	July	641	.72	462
	Aug.	358	1.18	422
	Sept.	213	1.58	337
	Oct.	166	1.92	318
	Nov.	177	1.89	334
	Dec.	188	1.66	313
	Total	7,718	.66	5,063

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
	Jan.	185	1.65	306
	Feb.	143	1.63	233
	Mar.	187	1.52	284
	Apr.	250	1.00	250
	May	606	.60	364
	June	1,399	.41	574
- 1953	July	353	.95	335
	Aug.	256	1.23	315
	Sept.	128	2.22	284
	Oct.	177	1.89	334
	Nov.	207	1.77	366
	Dec.	171	1.75	299
	Total	4,062	.97	3,944
	Jan.	177	1.76	312
	Feb.	143	1.65	236
	Mar.	161	1.46	235
	Apr.	221	.98	217
	May	436	.74	323
	June	217	1.17	254
- 1954	July	150	1.69	253
	Aug.	98	2.30	225
	Sept.	171	2.09	358
	Oct.	215	1.59	342
	Nov.	164	1.70	278
	Dec.	140	1.90	266
	Total	2,293	1.44	3,299
	Jan.	134	1.84	247
	Feb.	121	1.78	215
	Mar.	198	1.33	263
	Apr.	320	.82	262
	May	752	.50	376
	June	689	.55	379
- 1955	July	214	1.21	259
	Aug.	185	1.66	307
	Sept.	108	2.16	233
	Oct.	119	2.19	261
	Nov.	169	1.89	[illegible]
	Dec.	176	1.70	299
	Total	3,185	1.07	3,420
	Jan.	155	1.69	262
	Feb.	141	1.70	239
	Mar.	187	1.50	281
	Apr.	356	.72	256
	May	1,005	.45	452
	June	924	.44	406
- 1956	July	172	1.47	253
	Aug.	119	1.97	234
	Sept.	81	2.38	193
	Oct.	121	2.22	269
	Nov.	165	1.87	308
	Dec.	142	1.94	275
	Total	3,568	.96	3,428
	Jan.	164	1.80	296
	Feb.	168	1.55	260
	Mar.	167	1.56	260
	Apr.	398	.86	342
	May	1,375	.44	605
	June	2,859	.29	829
- 1957	July	1,952	.37	722
	Aug.	661	.83	549
	Sept.	314	1.21	380
	Oct.	292	1.78	520
	Nov.	299	1.44	431
	Dec.	239	1.71	408
	Total	8,888	.63	5,602
	Jan.	200	1.52	304
	Feb.	225	1.34	302
	Mar.	254	1.29	328
	Apr.	756	.53	401
	May	2,032	.31	630
	June	1,560	.40	624
- 1958	July	234	1.22	285
	Aug.	109	2.17	236
	Sept.	153	2.14	328
	Oct.	155	1.99	308
	Nov.	190	1.66	315
	Dec.	176	1.63	287
	Total	6,044	.72	4,348

To obtain mg/l multiply T/AF by 735.

Table 9

Colorado River Basin

Historical Flow and Quality of Water Data

Colorado River near Cisco, Utah

Units - 1000

Year	Month	Flow (A.F.)	Concen-tration (T./A.F.)	T.D.S. (Tons)
1959	Jan.	168	1.71	287
	Feb.	153	1.41	216
	Mar.	150	1.60	240
	Apr.	163	1.39	227
	May	535	.65	348
	June	924	.50	462
	July	214	1.15	246
	Aug.	160	1.91	306
	Sept.	124	2.14	265
	Oct.	250	1.43	358
	Nov.	210	1.31	275
	Dec.	163	1.54	251
	Total	3,214	1.08	3,481
1960	Jan.	164	1.51	248
	Feb.	143	1.51	216
	Mar.	273	1.22	333
	Apr.	629	.51	321
	May	758	.49	371
	June	1,068	.42	448
	July	250	1.04	260
	Aug.	105	1.96	206
	Sept.	117	2.16	253
	Oct.	153	1.94	297
	Nov.	177	1.67	296
	Dec.	165	1.48	244
	Total	4,002	.87	3,493
1961	Jan.	156	1.43	223
	Feb.	140	1.52	213
	Mar.	162	1.44	233
	Apr.	206	1.14	235
	May	677	.57	386
	June	664	.51	339
	July	130	1.62	211
	Aug.	138	2.01	277
	Sept.	316	1.49	471
	Oct.	357	1.07	382
	Nov.	252	1.23	310
	Dec.	197	1.40	276
	Total	3,395	1.05	3,556
1962	Jan.	182	1.29	235
	Feb.	261	1.12	292
	Mar.	246	1.05	258
	Apr.	1,054	.44	464
	May	1,603	.38	609
	June	1,400	.38	532
	July	765	.58	444
	Aug.	206	1.42	293
	Sept.	173	1.99	344
	Oct.	263	1.43	376
	Nov.	243	1.31	318
	Dec.	180	1.77	319
	Total	6,576	.68	4,484
1963	Jan.	163	1.52	248
	Feb.	193	1.51	292
	Mar.	219	1.30	285
	Apr.	245	.91	223
	May	517	.62	320
	June	332	.93	309
	July	114	1.94	221
	Aug.	168	1.94	326
	Sept.	183	1.80	329
	Oct.	134	2.14	287
	Nov.	179	1.62	290
	Dec.	138	1.84	254
	Total	2,585	1.31	3,384
1964	Jan.	132	1.85	244
	Feb.	121	1.79	217
	Mar.	128	1.87	239
	Apr.	214	1.11	238
	May	861	.50	430
	June	780	.50	390
	July	276	1.07	295
	Aug.	241	1.51	364
	Sept.	153	1.88	288
	Oct.	164	1.93	317
	Nov.	182	1.81	329
	Dec.	181	1.59	288
	Total	3,433	1.06	3,639
1965	Jan.	162	1.55	251
	Feb.	140	1.63	228
	Mar.	154	1.59	245
	Apr.	562	.68	382
	May	1,272	.39	496
	June	1,654	.38	629
	July	1,116	.52	580
	Aug.	447	.94	420
	Sept.	369	1.21	446
	Oct.	360	1.32	475
	Nov.	249	1.65	411
	Dec.	237	1.39	329
	Total	6,722	.73	4,892
1966	Jan.	200	1.38	276
	Feb.	169	1.34	226
	Mar.	278	.96	267
	Apr.	438	.61	267
	May	697	.53	369
	June	429	.83	356
	July	185	1.50	278
	Aug.	120	1.89	227
	Sept.	145	2.01	291
	Oct.	175	1.87	327
	Nov.	153	1.89	289
	Dec.	174	1.71	298
	Total	3,163	1.10	3,471
1967	Jan.	146	1.77	258
	Feb.	136	1.71	233
	Mar.	185	1.30	240
	Apr.	198	1.31	259
	May	462	.76	351
	June	713	.65	463
	July	327	1.09	356
	Aug.	175	1.76	308
	Sept.	178	1.77	315
	Oct.	174	1.39	242
	Nov.	211	1.39	293
	Dec.	241	1.18	284
	Total	3,146	1.14	3,602
1968	Jan.	205	1.18	242
	Feb.	193	1.20	232
	Mar.	171	1.41	241
	Apr.	230	.99	228
	May	667	.60	400
	June	1,171	.44	515
	July	306	1.08	330
	Aug.	365	1.23	449
	Sept.	159	1.72	273
	Oct.	213	1.63	347
	Nov.	257	1.28	329
	Dec.	248	1.14	283
	Total	4,185	.92	3,869
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
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	Aug.			
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	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			

To obtain mg/l multiply T/AF by 735.

Table 9
Colorado River Basin
Historical Flow and Quality of Water Data
Colorado River near Cisco, Utah

(Annual Summary)

Units - 1000

Year	Flow (A.F.)	Concentration (T./A.F.)	Concentration (Mg./1)	T.D.S. (Tons)
1941	7,067	.80	588	5,653
1942	7,098	.77	568	5,483
1943	5,214	.86	634	4,498
1944	5,840	.74	546	4,336
1945	5,504	.76	562	4,210
1946	4,058	.91	667	3,680
1947	6,258	.73	539	4,587
1948	6,291	.74	542	4,636
1949	6,338	.75	555	4,783
1950	4,074	.94	690	3,823
1951	3,986	.94	693	3,758
1952	7,718	.66	482	5,063
1953	4,062	.97	714	3,944
1954	2,293	1.44	1,060	3,299
1955	3,185	1.07	789	3,420
1956	3,568	.96	706	3,428
1957	8,888	.63	463	5,602
1958	6,044	.72	529	4,348
1959	3,214	1.08	796	3,481
1960	4,002	.87	642	3,493
1961	3,395	1.05	770	3,556
1962	6,576	.68	501	4,484
1963	2,585	1.31	962	3,384
1964	3,433	1.06	779	3,639
1965	6,722	.73	535	4,892
1966	3,163	1.10	807	3,471
1967	3,146	1.14	842	3,602
1968	4,185	.92	680	3,869
Total	137,907			116,422
Average	4,925	.84	620	4,158

Sampled quality record entire period.
Measured flow record entire period.

Table 10

Colorado River Basin

Historical Flow and Quality of Water Data

San Juan River near Archuleta, New Mexico

Units - 1000

Year	Month	Flow (A.F.)	Concen-tration (T./A.F.)	T.D.S. (Tons)
1941	Jan.	22	0.41	9
	Feb.	46	.35	16
	Mar.	98	.38	37
	Apr.	251	.21	53
	May	709	.16	113
	June	560	.12	68
	July	324	.14	46
	Aug.	84	.19	16
	Sept.	68	.24	16
	Oct.	273	.12	33
	Nov.	87	.17	15
	Dec.	52	.21	11
	Total	2,574	.17	430
1942	Jan.	45	.33	15
	Feb.	48	.25	12
	Mar.	54	.42	23
	Apr.	383	.21	82
	May	320	.15	48
	June	310	.12	38
	July	76	.18	14
	Aug.	41	.22	9
	Sept.	28	.25	7
	Oct.	23	.26	6
	Nov.	22	.27	6
	Dec.	16	.38	6
	Total	1,366	.19	266
1943	Jan.	16	.44	7
	Feb.	26	.35	9
	Mar.	55	.38	21
	Apr.	198	.19	37
	May	184	.16	30
	June	134	.15	20
	July	51	.24	12
	Aug.	48	.21	10
	Sept.	28	.25	7
	Oct.	35	.20	7
	Nov.	24	.29	7
	Dec.	19	.32	6
	Total	818	.21	173
1944	Jan.	16	.38	6
	Feb.	19	.32	6
	Mar.	34	.47	16
	Apr.	131	.21	27
	May	371	.16	61
	June	382	.13	49
	July	134	.16	22
	Aug.	45	.20	9
	Sept.	43	.23	10
	Oct.	41	.22	9
	Nov.	21	.29	6
	Dec.	14	.43	6
	Total	1,251	.18	227
1945	Jan.	14	.43	6
	Feb.	22	.45	10
	Mar.	35	.49	17
	Apr.	143	.20	28
	May	278	.16	44
	June	209	.13	28
	July	68	.21	14
	Aug.	40	.22	9
	Sept.	21	.24	5
	Oct.	30	.37	11
	Nov.	19	.37	7
	Dec.	12	.50	6
	Total	891	.21	185
1946	Jan.	14	.43	6
	Feb.	17	.47	8
	Mar.	22	.50	11
	Apr.	66	.23	15
	May	73	.18	13
	June	87	.18	16
	July	27	.33	9
	Aug.	40	.35	14
	Sept.	29	.31	9
	Oct.	36	.31	11
	Nov.	26	.35	9
	Dec.	19	.32	6
	Total	456	.28	127
1947	Jan.	15	0.40	6
	Feb.	24	.38	9
	Mar.	32	.34	11
	Apr.	50	.24	12
	May	186	.17	32
	June	140	.13	18
	July	43	.28	12
	Aug.	73	.30	22
	Sept.	56	.23	13
	Oct.	77	.21	16
	Nov.	37	.22	8
	Dec.	27	.26	7
	Total	760	.22	166
1948	Jan.	27	.26	7
	Feb.	39	.33	13
	Mar.	43	.35	15
	Apr.	246	.20	49
	May	306	.14	43
	June	338	.12	40
	July	79	.16	13
	Aug.	49	.24	12
	Sept.	22	.32	7
	Oct.	23	.35	8
	Nov.	18	.39	7
	Dec.	13	.46	6
	Total	1,203	.18	220
1949	Jan.	16	.44	7
	Feb.	25	.36	9
	Mar.	73	.37	27
	Apr.	228	.24	55
	May	318	.15	48
	June	406	.13	53
	July	199	.15	30
	Aug.	57	.24	14
	Sept.	33	.27	9
	Oct.	30	.30	9
	Nov.	21	.38	8
	Dec.	14	.50	7
	Total	1,420	.19	276
1950	Jan.	16	.37	6
	Feb.	29	.41	12
	Mar.	31	.42	13
	Apr.	116	.19	22
	May	126	.15	19
	June	112	.16	18
	July	44	.27	12
	Aug.	20	.35	7
	Sept.	24	.38	9
	Oct.	20	.35	7
	Nov.	14	.50	7
	Dec.	12	.50	6
	Total	564	.24	138
1951	Jan.	10	.50	5
	Feb.	11	.45	5
	Mar.	20	.45	9
	Apr.	35	.29	10
	May	117	.18	21
	June	94	.17	16
	July	21	.38	8
	Aug.	33	.36	12
	Sept.	22	.36	8
	Oct.	17	.47	8
	Nov.	15	.47	7
	Dec.	18	.44	8
	Total	413	.28	117
1952	Jan.	19	.53	10
	Feb.	19	.53	10
	Mar.	47	.49	23
	Apr.	326	.26	85
	May	396	.16	63
	June	454	.13	59
	July	136	.18	24
	Aug.	66	.26	17
	Sept.	33	.27	9
	Oct.	22	.32	7
	Nov.	16	.44	7
	Dec.	18	.39	7
	Total	1,552	.21	321
1953	Jan.	18	0.39	7
	Feb.	18	.39	7
	Mar.	37	.41	15
	Apr.	75	.24	18
	May	117	.19	22
	June	148	.15	22
	July	41	.32	13
	Aug.	33	.33	11
	Sept.	16	.44	7
	Oct.	23	.43	10
	Nov.	23	.43	10
	Dec.	14	.50	7
	Total	563	.26	149
1954	Jan.	11	.45	5
	Feb.	21	.48	10
	Mar.	28	.46	13
	Apr.	90	.21	19
	May	143	.18	26
	June	67	.19	13
	July	37	.41	15
	Aug.	45	.29	13
	Sept.	30	.43	13
	Oct.	42	.24	10
	Nov.	18	.39	7
	Dec.	13	.46	6
	Total	545	.28	150
1955	Jan.	12	.42	5
	Feb.	13	.31	4
	Mar.	27	.37	10
	Apr.	45	.24	11
	May	132	.18	24
	June	119	.16	19
	July	42	.29	12
	Aug.	67	.28	19
	Sept.	28	.29	8
	Oct.	20	.30	6
	Nov.	17	.35	6
	Dec.	15	.40	6
	Total	537	.24	130
1956	Jan.	16	.38	6
	Feb.	15	.40	6
	Mar.	48	.33	16
	Apr.	79	.20	16
	May	173	.14	24
	June	117	.15	18
	July	25	.32	8
	Aug.	23	.35	8
	Sept.	11	.36	4
	Oct.	12	.42	5
	Nov.	11	.45	5
	Dec.	9	.44	4
	Total	539	.22	120
1957	Jan.	13	.46	6
	Feb.	30	.47	14
	Mar.	46	.43	20
	Apr.	120	.28	34
	May	222	.19	42
	June	480	.13	62
	July	326	.16	52
	Aug.	164	.22	36
	Sept.	67	.19	13
	Oct.	67	.30	20
	Nov.	68	.26	18
	Dec.	44	.30	13
	Total	1,647	.20	330
1958	Jan.	22	.36	8
	Feb.	51	.43	22
	Mar.	77	.42	32
	Apr.	279	.30	84
	May	460	.17	78
	June	270	.13	35
	July	42	.26	11
	Aug.	35	.31	11
	Sept.	40	.30	12
	Oct.	25	.36	9
	Nov.	17	.41	7
	Dec.	14	.42	6
	Total	1,332	.24	315

To obtain mg/l multiply T/AF by 735.

Table 10
Colorado River Basin
Historical Flow and Quality of Water Data
San Juan River near Archuleta, New Mexico
Units - 1000

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
- 1959	Jan.	11	0.46	5
	Feb.	14	.44	6
	Mar.	18	.42	8
	Apr.	37	.30	11
	May	87	.18	16
	June	84	.16	13
	July	18	.32	6
	Aug.	34	.33	11
	Sept.	15	.34	5
	Oct.	60	.30	18
	Nov.	39	.30	12
	Dec.	19	.37	7
	Total	436	.27	118
- 1960	Jan.	14	.43	6
	Feb.	16	.42	7
	Mar.	175	.34	60
	Apr.	240	.19	46
	May	193	.17	33
	June	232	.13	30
	July	55	.23	13
	Aug.	25	.29	7
	Sept.	23	.31	7
	Oct.	26	.37	10
	Nov.	16	.42	7
	Dec.	14	.54	7
	Total	1,029	.23	233
- 1961	Jan.	12	.45	5
	Feb.	16	.43	7
	Mar.	43	.44	19
	Apr.	113	.26	29
	May	192	.15	29
	June	122	.16	19
	July	38	.28	11
	Aug.	52	.28	15
	Sept.	58	.25	15
	Oct.	52	.24	12
	Nov.	34	.28	10
	Dec.	18	.31	6
	Total	750	.24	177
- 1962	Jan.	15	.37	6
	Feb.	42	.38	16
	Mar.	51	.38	20
	Apr.	242	.20	48
	May	228	.14	32
	June	165	.14	23
	July	39	.19	7
	Aug.	29	.25	7
	Sept.	19	.25	5
	Oct.	18	.31	6
	Nov.	14	.33	5
	Dec.	10	.37	4
	Total	872	.21	179
- 1963	Jan.	7	.39	3
	Feb.	8	.43	4
	Mar.	15	.39	6
	Apr.	31	.38	12
	May	19	.26	5
	June	19	.19	4
	July	20	.18	4
	Aug.	21	.19	4
	Sept.	20	.20	4
	Oct.	24	.23	6
	Nov.	24	.24	6
	Dec.	24	.28	7
	Total	232	.28	65
- 1964	Jan.	17	.32	6
	Feb.	13	.31	4
	Mar.	13	.32	4
	Apr.	15	.32	5
	May	34	.31	10
	June	82	.28	23
	July	108	.25	27
	Aug.	48	.23	11
	Sept.	26	.22	6
	Oct.	28	.23	6
	Nov.	21	.27	6
	Dec.	32	.28	9
	Total	437	.27	117

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
- 1965	Jan.	90	0.29	26
	Feb.	92	.30	28
	Mar.	52	.36	19
	Apr.	85	.35	30
	May	138	.29	40
	June	215	.20	43
	July	102	.18	18
	Aug.	136	.17	23
	Sept.	112	.17	19
	Oct.	131	.13	17
	Nov.	180	.16	29
	Dec.	178	.18	32
	Total	1,511	.21	324
- 1966	Jan.	168	.21	35
	Feb.	94	.26	24
	Mar.	114	.29	33
	Apr.	181	.28	51
	May	130	.26	34
	June	27	.22	6
	July	28	.17	5
	Aug.	29	.18	5
	Sept.	27	.17	5
	Oct.	91	.18	16
	Nov.	47	.20	9
	Dec.	25	.24	6
	Total	961	.24	229
- 1967	Jan.	25	.26	6
	Feb.	45	.26	12
	Mar.	70	.26	18
	Apr.	23	.27	6
	May	17	.31	5
	June	18	.35	6
	July	20	.34	7
	Aug.	62	.29	18
	Sept.	59	.26	15
	Oct.	21	.23	5
	Nov.	21	.26	5
	Dec.	21	.28	6
	Total	402	.27	109
- 1968	Jan.	19	.29	6
	Feb.	20	.26	5
	Mar.	18	.29	5
	Apr.	60	.27	16
	May	49	.26	13
	June	28	.26	7
	July	30	.28	8
	Aug.	39	.27	11
	Sept.	47	.25	12
	Oct.	35	.25	9
	Nov.	23	.24	6
	Dec.	24	.23	6
	Total	392	.27	104
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			

To obtain mg/l multiply T/AF by 735.

Table 10
Colorado River Basin
Historical Flow and Quality of Water Data
San Juan River near Archuleta, New Mexico

(Annual Summary)

Units - 1000

Year	Flow	Concentration		T.D.S.
	(A.F.)	(T./A.F.)	(Mg./l)	(Tons)
1941	2,574	0.17	123	430
1942	1,366	.19	143	266
1943	818	.21	155	173
1944	1,251	.18	133	227
1945	891	.21	153	185
1946	456	.28	205	127
1947	760	.22	161	166
1948	1,203	.18	134	220
1949	1,420	.19	142	276
1950	564	.24	180	138
1951	413	.28	208	117
1952	1,552	.21	152	321
1953	563	.26	195	149
1954	545	.28	202	150
1955	537	.24	178	130
1956	539	.22	164	120
1957	1,647	.20	147	330
1958	1,332	.24	174	315
1959	436	.27	199	118
1960	1,029	.23	166	233
1961	750	.24	173	177
1962	872	.21	151	179
1963	232	.28	206	65
1964	437	.27	197	117
1965	1,511	.21	158	324
1966	961	.24	175	229
1967	402	.27	199	109
1968	392	.27	195	104
Total	25,453			5,495
Average	909	.22	158	196

Sampled quality record, October 1945 to December 1968; remainder by correlation.

Measured flow record entire period.

Adjusted quality and flow record for station near Blanco, October 1945 to November 1954.

Table II

Colorado River Basin

Historical Flow and Quality of Water Data

San Juan River near Bluff, Utah

Units-1000

Year	Month	Flow (A.F.)	Concen-tration (T./A.F.)	T.D.S. (Tons)
	Jan.	78	1.01	79
	Feb.	127	.98	124
	Mar.	211	.78	165
	Apr.	392	.62	243
	May	1,323	.50	662
	June	915	.30	275
-1941	July	526	.30	158
	Aug.	174	.70	122
	Sept.	202	.87	176
	Oct.	655	.64	419
	Nov.	191	.61	117
	Dec.	105	.81	85
Total		4,899	.54	2,625
	Jan.	81	.93	75
	Feb.	68	.93	63
	Mar.	126	.95	120
	Apr.	602	.51	307
	May	479	.38	182
	June	533	.26	139
-1942	July	150	.48	72
	Aug.	51	.82	42
	Sept.	38	1.00	38
	Oct.	37	1.22	45
	Nov.	39	1.23	48
	Dec.	43	1.26	54
Total		2,247	.53	1,185
	Jan.	43	1.26	54
	Feb.	49	1.18	58
	Mar.	95	1.09	104
	Apr.	294	.47	138
	May	332	.39	129
	June	251	.38	96
-1943	July	106	.57	60
	Aug.	91	1.01	92
	Sept.	62	.90	56
	Oct.	58	1.00	58
	Nov.	59	.97	57
	Dec.	51	1.12	57
Total		1,494	.64	959
	Jan.	37	1.16	43
	Feb.	49	1.14	56
	Mar.	76	1.06	81
	Apr.	204	.62	126
	May	640	.36	230
	June	705	.25	176
-1944	July	283	.35	99
	Aug.	61	.85	52
	Sept.	66	.92	61
	Oct.	75	.91	68
	Nov.	52	1.12	58
	Dec.	43	1.19	51
Total		2,291	.48	1,101
	Jan.	41	1.22	50
	Feb.	63	1.13	71
	Mar.	72	1.03	74
	Apr.	196	.61	120
	May	456	.35	160
	June	377	.29	109
-1945	July	128	.50	64
	Aug.	96	1.13	108
	Sept.	21	1.18	25
	Oct.	62	1.10	68
	Nov.	46	1.04	48
	Dec.	30	1.27	38
Total		1,588	.59	935
	Jan.	37	1.14	42
	Feb.	36	1.19	43
	Mar.	47	1.04	49
	Apr.	95	.66	63
	May	125	.49	61
-1946	June	204	.40	82
	July	63	.86	54
	Aug.	75	1.12	84
	Sept.	44	.93	41
	Oct.	55	.98	54
	Nov.	60	1.02	61
	Dec.	46	1.02	47
Total		887	.77	681
	Jan.	31	1.13	35
	Feb.	45	1.07	48
	Mar.	51	.90	46
	Apr.	68	.63	43
	May	329	.38	125
	June	276	.30	83
-1947	July	110	.41	45
	Aug.	294	1.01	296
	Sept.	124	.73	91
	Oct.	207	.79	163
	Nov.	77	.73	56
	Dec.	65	.86	56
Total		1,677	.65	1,087
	Jan.	52	.83	43
	Feb.	79	.84	66
	Mar.	89	.83	74
	Apr.	358	.37	133
	May	519	.27	140
	June	603	.28	169
-1948	July	147	.41	60
	Aug.	86	.78	67
	Sept.	36	1.11	40
	Oct.	75	1.05	79
	Nov.	55	1.07	59
	Dec.	41	1.12	46
Total		2,140	.46	976
	Jan.	63	1.11	70
	Feb.	74	.99	73
	Mar.	152	.81	123
	Apr.	338	.45	152
	May	503	.31	156
	June	748	.31	232
-1949	July	342	.33	113
	Aug.	90	.66	59
	Sept.	41	1.05	43
	Oct.	56	1.00	56
	Nov.	45	1.07	48
	Dec.	35	1.23	43
Total		2,487	.47	1,168
	Jan.	41	1.12	46
	Feb.	49	1.08	53
	Mar.	56	.93	52
	Apr.	136	.46	62
	May	169	.40	68
	June	191	.38	73
-1950	July	68	.72	49
	Aug.	15	1.13	17
	Sept.	42	1.14	48
	Oct.	30	1.07	32
	Nov.	25	1.44	36
	Dec.	32	1.34	43
Total		854	.68	579
	Jan.	30	1.30	39
	Feb.	29	1.41	41
	Mar.	34	1.15	39
	Apr.	34	.85	29
	May	142	.51	72
	June	188	.36	68
-1951	July	30	.80	24
	Aug.	49	1.06	52
	Sept.	45	1.07	48
	Oct.	35	1.23	43
	Nov.	39	1.10	43
	Dec.	36	1.28	46
Total		691	.79	544
	Jan.	88	1.16	102
	Feb.	40	1.20	48
	Mar.	87	1.03	90
	Apr.	453	.42	190
	May	618	.30	185
-1952	June	769	.24	185
	July	238	.42	100
	Aug.	83	.69	57
	Sept.	56	.93	52
	Oct.	38	1.05	40
	Nov.	41	1.29	53
	Dec.	43	1.26	54
Total		2,554	.45	1,156
	Jan.	42	1.24	52
	Feb.	36	1.17	42
	Mar.	56	1.02	57
	Apr.	107	.64	68
	May	156	.44	69
	June	267	.27	72
-1953	July	77	.84	65
	Aug.	71	1.15	82
	Sept.	12	1.50	18
	Oct.	54	1.28	69
	Nov.	55	1.13	62
	Dec.	34	1.31	45
Total		967	.73	701
	Jan.	32	1.34	43
	Feb.	36	1.17	42
	Mar.	48	1.02	49
	Apr.	113	.53	60
	May	218	.39	85
	June	120	.48	58
-1954	July	120	1.03	123
	Aug.	66	.86	57
	Sept.	89	1.19	106
	Oct.	95	.75	71
	Nov.	39	1.05	41
	Dec.	35	1.26	44
Total		1,011	.77	779
	Jan.	31	1.26	39
	Feb.	34	1.12	38
	Mar.	63	1.00	63
	Apr.	62	.74	46
	May	186	.38	71
	June	208	.32	67
-1955	July	65	.88	57
	Aug.	142	1.07	152
	Sept.	28	.82	23
	Oct.	25	1.00	25
	Nov.	31	1.26	39
	Dec.	35	1.34	47
Total		910	.73	667
	Jan.	40	1.22	49
	Feb.	34	1.29	44
	Mar.	74	.83	61
	Apr.	107	.50	54
	May	241	.35	84
	June	203	.31	63
-1956	July	31	1.10	34
	Aug.	36	1.33	48
	Sept.	4	1.50	6
	Oct.	13	1.54	20
	Nov.	30	1.23	37
	Dec.	25	1.40	35
Total		838	.64	535
	Jan.	38	1.26	48
	Feb.	64	1.05	67
	Mar.	71	.97	69
	Apr.	171	.55	94
	May	327	.48	157
	June	787	.28	220
-1957	July	566	.38	215
	Aug.	364	.63	229
	Sept.	142	.68	97
	Oct.	150	.86	129
	Nov.	141	.72	102
	Dec.	88	.81	71
Total		2,909	.51	1,498
	Jan.	53	1.02	54
	Feb.	119	.92	109
	Mar.	159	.87	139
	Apr.	413	.48	198
	May	743	.26	193
-1958	June	507	.25	126
	July	74	.65	48
	Aug.	43	1.02	43
	Sept.	61	.95	58
	Oct.	47	1.04	49
	Nov.	43	1.23	53
	Dec.	36	1.28	46
Total		2,298	.49	1,116

To obtain mg/l multiply T/AF by 735.

Table 11

Colorado River Basin

Historical Flow and Quality of Water Data

San Juan River near Bluff, Utah

Units - 1000

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)	Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)	Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
	Jan.	30	1.39	42		Jan.	122	0.77	94		Jan.			
	Feb.	31	1.36	42		Feb.	120	.70	84		Feb.			
	Mar.	32	1.27	41		Mar.	85	.93	79		Mar.			
	Apr.	39	.94	37		Apr.	165	.62	102		Apr.			
	May	111	.52	58		May	288	.45	130		May			
	June	156	.39	61		June	419	.38	159		June			
-1959	July	18	.81	15	-1965	July	295	.45	133		July			
	Aug.	64	1.13	72		Aug.	218	.65	142		Aug.			
	Sept.	11	1.53	17		Sept.	177	.56	99		Sept.			
	Oct.	92	.86	79		Oct.	190	.60	114		Oct.			
	Nov.	82	.82	67		Nov.	232	.50	116		Nov.			
	Dec.	46	1.02	47		Dec.	235	.54	127		Dec.			
Total		712	.81	578	Total		2,546	.54	1,379	Total				
	Jan.	37	1.26	47		Jan.	198	0.54	107		Jan.			
	Feb.	43	1.09	47		Feb.	129	.65	84		Feb.			
	Mar.	260	.73	190		Mar.	199	.68	135		Mar.			
	Apr.	336	.32	108		Apr.	252	.48	121		Apr.			
	May	285	.34	97		May	267	.42	112		May			
	June	382	.27	103		June	127	.56	71		June			
-1960	July	92	.53	49	-1966	July	54	1.01	55		July			
	Aug.	18	1.11	20		Aug.	44	1.30	57		Aug.			
	Sept.	17	1.24	21		Sept.	42	1.25	52		Sept.			
	Oct.	58	1.13	66		Oct.	94	.66	62		Oct.			
	Nov.	39	1.22	48		Nov.	70	.86	60		Nov.			
	Dec.	40	1.27	51		Dec.	72	1.11	80		Dec.			
Total		1,607	.53	847	Total		1,548	.64	996	Total				
	Jan.	35	1.33	47		Jan.	58	1.07	62		Jan.			
	Feb.	41	1.31	54		Feb.	64	.92	59		Feb.			
	Mar.	66	1.02	67		Mar.	79	.71	56		Mar.			
	Apr.	157	.56	88		Apr.	31	1.15	36		Apr.			
	May	285	.32	91		May	78	.76	59		May			
	June	227	.31	70		June	89	.91	81		June			
-1961	July	43	.83	36	-1967	July	39	1.35	53		July			
	Aug.	87	1.05	91		Aug.	151	1.29	195		Aug.			
	Sept.	109	.88	96		Sept.	94	.96	90		Sept.			
	Oct.	98	.77	75		Oct.	31	1.46	45		Oct.			
	Nov.	72	.93	67		Nov.	38	1.26	48		Nov.			
	Dec.	44	1.22	54		Dec.	39	1.20	47		Dec.			
Total		1,264	.66	836	Total		791	1.05	831	Total				
	Jan.	36	1.24	45		Jan.	36	1.22	44		Jan.			
	Feb.	94	.95	89		Feb.	54	1.29	70		Feb.			
	Mar.	73	.99	72		Mar.	50	1.25	62		Mar.			
	Apr.	315	.37	117		Apr.	83	.75	62		Apr.			
	May	346	.30	104		May	148	.54	80		May			
	June	297	.32	95		June	240	.37	89		June			
-1962	July	88	.59	52	-1968	July	82	.93	76		July			
	Aug.	23	1.02	23		Aug.	176	1.04	183		Aug.			
	Sept.	26	1.41	37		Sept.	41	1.00	41		Sept.			
	Oct.	104	1.32	137		Oct.	56	1.09	61		Oct.			
	Nov.	45	1.34	60		Nov.	49	1.18	58		Nov.			
	Dec.	33	1.40	46		Dec.	45	1.07	48		Dec.			
Total		1,480	.59	877	Total		1,060	.82	874	Total				
	Jan.	25	1.66	42		Jan.					Jan.			
	Feb.	39	1.44	56		Feb.					Feb.			
	Mar.	40	1.25	50		Mar.					Mar.			
	Apr.	64	.78	50		Apr.					Apr.			
	May	95	.72	68		May					May			
-1963	June	47	.82	39		June					June			
	July	15	1.60	24		July					July			
	Aug.	48	1.57	75		Aug.					Aug.			
	Sept.	70	1.09	76		Sept.					Sept.			
	Oct.	41	1.32	54		Oct.					Oct.			
	Nov.	47	1.10	52		Nov.					Nov.			
	Dec.	48	1.03	49		Dec.					Dec.			
Total		579	1.10	635	Total					Total				
	Jan.	44	1.14	50		Jan.					Jan.			
	Feb.	30	1.27	38		Feb.					Feb.			
	Mar.	28	1.46	41		Mar.					Mar.			
	Apr.	30	1.40	42		Apr.					Apr.			
	May	103	.57	59		May					May			
	June	121	.58	70		June					June			
-1964	July	113	.76	86		July					July			
	Aug.	131	1.07	140		Aug.					Aug.			
	Sept.	56	1.36	76		Sept.					Sept.			
	Oct.	37	1.26	47		Oct.					Oct.			
	Nov.	42	1.43	60		Nov.					Nov.			
	Dec.	60	1.20	72		Dec.					Dec.			
Total		795	.98	781	Total					Total				

To obtain mg/l multiply T/AF by 735.

Table II
Colorado River Basin
Historical Flow and Quality of Water Data
San Juan River near Bluff, Utah

(Annual Summary)

Units - 1000

Year	Flow (A.F.)	Concentration (T./A.F.)	Concentration (Mg./l)	T.D.S. (Tons)
1941	4,899	.54	394	2,625
1942	2,247	.53	388	1,185
1943	1,494	.64	472	959
1944	2,291	.48	353	1,101
1945	1,588	.59	433	935
1946	887	.77	564	681
1947	1,677	.65	476	1,087
1948	2,140	.46	335	976
1949	2,487	.47	345	1,168
1950	854	.68	498	579
1951	691	.79	579	544
1952	5,554	.45	333	1,156
1953	967	.73	533	701
1954	1,011	.77	566	779
1955	910	.73	539	667
1956	838	.64	469	535
1957	2,909	.51	378	1,498
1958	2,298	.49	357	1,116
1959	712	.81	597	578
1960	1,607	.53	387	847
1961	1,264	.66	486	836
1962	1,480	.59	436	877
1963	579	1.10	806	635
1964	795	.98	722	781
1965	2,546	.54	398	1,379
1966	1,548	.64	473	996
1967	791	1.05	772	831
1968	1,060	.82	606	874
Total	45,124			26,926
Average	1,612	.60	439	962

Sampled quality record entire period.
Measured flow records entire period.

Table 12

Colorado River Basin

Historical Flow and Quality of Water Data

Colorado River at Lees Ferry, Arizona

Units - 1000

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
-1941	Jan.	348	1.36	474
	Feb.	423	1.29	546
	Mar.	669	1.12	749
	Apr.	1,091	.79	862
	May	4,974	.45	2,239
	June	4,004	.38	1,522
	July	1,666	.51	850
	Aug.	798	1.16	925
	Sept.	608	1.35	821
	Oct.	1,797	1.09	1,959
	Nov.	903	.94	849
	Dec.	576	1.19	685
Total		17,857	.70	12,481
-1942	Jan.	407	1.34	545
	Feb.	396	1.28	507
	Mar.	630	1.16	731
	Apr.	2,844	.55	1,564
	May	3,209	.46	1,476
	June	4,202	.29	1,219
	July	1,317	.57	751
	Aug.	454	1.08	490
	Sept.	275	1.59	438
	Oct.	334	1.58	528
	Nov.	368	1.58	582
	Dec.	357	1.54	550
Total		14,793	.63	9,381
-1943	Jan.	330	1.50	494
	Feb.	332	1.41	469
	Mar.	516	1.19	614
	Apr.	1,450	.67	971
	May	2,158	.43	928
	June	2,729	.40	1,092
	July	1,429	.47	672
	Aug.	793	1.09	864
	Sept.	447	1.15	514
	Oct.	378	1.60	604
	Nov.	456	1.35	616
	Dec.	395	1.36	537
Total		11,413	.73	8,375
-1944	Jan.	278	1.50	418
	Feb.	344	1.32	454
	Mar.	509	1.31	668
	Apr.	1,027	.89	914
	May	3,251	.47	1,528
	June	4,136	.32	1,323
	July	1,782	.45	802
	Aug.	417	1.07	446
	Sept.	229	1.50	343
	Oct.	342	1.66	567
	Nov.	384	1.51	579
	Dec.	320	1.51	483
Total		13,019	.65	8,525
-1945	Jan.	325	1.48	481
	Feb.	352	1.39	489
	Mar.	437	1.28	559
	Apr.	755	.99	748
	May	2,805	.44	1,234
	June	2,761	.37	1,021
	July	1,668	.47	784
	Aug.	1,011	.89	900
	Sept.	370	1.28	474
	Oct.	505	1.51	763
	Nov.	443	1.34	594
	Dec.	337	1.35	454
Total		11,769	.72	8,501
-1946	Jan.	366	1.28	468
	Feb.	319	1.24	396
	Mar.	496	1.15	570
	Apr.	1,013	.83	841
	May	1,732	.47	814
	June	1,993	.43	857
	July	730	.73	533
	Aug.	478	1.28	612
	Sept.	310	1.62	502
	Oct.	403	1.50	604
	Nov.	466	1.30	607
	Dec.	445	1.22	542
Total		8,751	.84	7,346
-1947	Jan.	277	1.40	388
	Feb.	357	1.29	462
	Mar.	654	1.09	713
	Apr.	780	.78	608
	May	3,121	.39	1,217
	June	3,275	.40	1,310
	July	1,926	.43	828
	Aug.	1,203	.98	1,179
	Sept.	584	1.13	660
	Oct.	818	1.17	958
	Nov.	585	1.07	626
	Dec.	466	1.21	564
Total		14,046	.68	9,513
-1948	Jan.	406	1.18	479
	Feb.	458	1.14	522
	Mar.	645	1.14	735
	Apr.	1,703	.64	1,090
	May	3,507	.38	1,333
	June	3,339	.34	1,135
	July	980	.65	637
	Aug.	531	1.23	653
	Sept.	230	1.40	322
	Oct.	331	1.65	545
	Nov.	408	1.46	595
	Dec.	347	1.40	485
Total		12,885	.66	8,531
-1949	Jan.	337	1.39	469
	Feb.	361	1.25	451
	Mar.	706	1.18	834
	Apr.	1,307	.78	1,020
	May	3,098	.43	1,332
	June	4,419	.41	1,812
	July	2,137	.52	1,111
	Aug.	576	1.00	576
	Sept.	313	1.51	473
	Oct.	509	1.48	753
	Nov.	473	1.31	619
	Dec.	368	1.37	504
Total		14,604	.68	9,954
-1950	Jan.	350	1.41	493
	Feb.	399	1.23	490
	Mar.	650	1.11	721
	Apr.	1,217	.74	900
	May	1,971	.49	966
	June	2,979	.37	1,102
	July	1,377	.67	923
	Aug.	422	1.02	430
	Sept.	330	1.47	485
	Oct.	342	1.47	502
	Nov.	350	1.55	542
	Dec.	415	1.31	544
Total		10,802	.75	8,098
-1951	Jan.	315	1.43	451
	Feb.	361	1.25	451
	Mar.	418	1.19	497
	Apr.	531	1.00	531
	May	1,645	.57	938
	June	2,886	.41	1,184
	July	1,357	.48	651
	Aug.	787	1.11	874
	Sept.	411	1.32	542
	Oct.	412	1.47	606
	Nov.	445	1.41	628
	Dec.	333	1.44	480
Total		9,901	.79	7,833
-1952	Jan.	476	1.23	586
	Feb.	379	1.26	478
	Mar.	440	1.31	576
	Apr.	2,267	.74	1,677
	May	5,081	.41	2,083
	June	5,192	.36	1,869
	July	1,573	.55	865
	Aug.	821	1.06	870
	Sept.	542	1.31	710
	Oct.	368	1.43	527
	Nov.	386	1.55	599
	Dec.	378	1.47	556
Total		17,903	.64	11,396
-1953	Jan.	393	1.36	534
	Feb.	365	1.30	475
	Mar.	458	1.22	558
	Apr.	529	1.07	566
	May	1,047	.69	723
	June	2,992	.38	1,137
	July	950	.64	608
	Aug.	661	1.19	787
	Sept.	258	1.59	410
	Oct.	321	1.77	568
	Nov.	414	1.50	621
	Dec.	341	1.46	498
Total		8,729	.86	7,486
-1954	Jan.	319	1.46	466
	Feb.	342	1.30	444
	Mar.	393	1.24	487
	Apr.	546	1.00	546
	May	1,277	.56	715
	June	792	.63	499
	July	647	.87	563
	Aug.	321	1.19	382
	Sept.	389	1.66	645
	Oct.	512	1.43	733
	Nov.	349	1.39	485
	Dec.	278	1.51	421
Total		6,165	1.04	6,386
-1955	Jan.	244	1.58	386
	Feb.	243	1.39	338
	Mar.	580	1.29	748
	Apr.	617	1.05	649
	May	1,570	.56	879
	June	1,586	.49	777
	July	571	.70	399
	Aug.	510	1.40	713
	Sept.	230	1.60	368
	Oct.	214	1.70	363
	Nov.	275	1.67	458
	Dec.	326	1.44	470
Total		6,966	.94	6,548
-1956	Jan.	373	1.28	477
	Feb.	280	1.39	390
	Mar.	511	1.16	592
	Apr.	898	.75	673
	May	2,190	.48	1,051
	June	2,594	.39	1,012
	July	557	.75	418
	Aug.	356	1.33	473
	Sept.	166	1.48	246
	Oct.	186	1.74	324
	Nov.	300	1.58	474
	Dec.	247	1.55	383
Total		8,658	.75	6,513
-1957	Jan.	284	1.46	415
	Feb.	323	1.34	433
	Mar.	498	1.23	613
	Apr.	828	.90	745
	May	2,569	.56	1,439
	June	5,645	.39	2,201
	July	4,015	.43	1,727
	Aug.	1,604	.78	1,251
	Sept.	822	1.03	847
	Oct.	748	1.54	1,150
	Nov.	848	1.39	1,179
	Dec.	516	1.25	646
Total		18,700	.68	12,646
-1958	Jan.	397	1.27	504
	Feb.	536	1.18	632
	Mar.	696	1.10	766
	Apr.	1,574	.64	1,007
	May	3,992	.46	1,836
	June	3,678	.40	1,471
	July	628	.74	465
	Aug.	286	1.43	409
	Sept.	319	1.69	540
	Oct.	310	1.63	505
	Nov.	357	1.65	589
	Dec.	366	1.52	556
Total		13,139	.71	9,280

To obtain mg/l multiply T/AF by 735.

Table 12

Colorado River Basin

Historical Flow and Quality of Water Data

Colorado River at Lees Ferry, Arizona

Units - 1000

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
-1959	Jan.	315	1.48	466
	Feb.	315	1.36	428
	Mar.	344	1.37	471
	Apr.	420	1.16	487
	May	1,025	.70	718
	June	1,836	.48	881
	July	782	.63	493
	Aug.	425	1.43	608
	Sept.	246	1.68	413
	Oct.	502	1.41	708
	Nov.	499	1.21	604
	Dec.	352	1.39	489
	Total	7,061	.96	6,766
-1960	Jan.	305	1.54	470
	Feb.	318	1.34	426
	Mar.	745	1.18	879
	Apr.	1,610	.62	998
	May	1,564	.51	798
	June	2,239	.43	963
	July	647	.69	446
	Aug.	208	1.38	287
	Sept.	193	1.90	367
	Oct.	341	1.67	569
	Nov.	345	1.47	507
	Dec.	275	1.39	382
	Total	8,790	.81	7,092
-1961	Jan.	266	1.48	394
	Feb.	331	1.34	444
	Mar.	362	1.34	485
	Apr.	567	1.02	578
	May	1,153	.59	680
	June	1,588	.45	715
	July	369	.89	328
	Aug.	336	1.65	554
	Sept.	710	1.61	1,143
	Oct.	725	1.01	732
	Nov.	527	1.04	548
	Dec.	380	1.22	464
	Total	7,314	.97	7,065
-1962	Jan.	349	1.24	433
	Feb.	791	1.03	815
	Mar.	598	1.13	676
	Apr.	2,391	.71	1,698
	May	3,633	.44	1,599
	June	2,876	.45	1,294
	July	1,717	.57	979
	Aug.	469	1.02	478
	Sept.	315	1.61	507
	Oct.	539	1.52	819
	Nov.	428	1.28	548
	Dec.	333	1.42	473
	Total	14,439	.71	10,319
-1963	Jan.	169	1.69	286
	Feb.	369	1.35	498
	Mar.	188	1.35	254
	Apr.	60	1.44	86
	May	62	1.30	81
	June	140	1.13	158
	July	90	.95	86
	Aug.	62	.96	60
	Sept.	60	.90	54
	Oct.	61	.88	54
	Nov.	60	.95	57
	Dec.	63	1.34	84
	Total	1,384	1.27	1,758
-1964	Jan.	71	1.33	94
	Feb.	231	1.33	307
	Mar.	388	1.29	500
	Apr.	772	1.24	956
	May	319	1.22	389
	June	60	1.23	74
	July	60	1.25	75
	Aug.	174	1.24	216
	Sept.	156	.69	108
	Oct.	268	.63	169
	Nov.	347	.84	292
	Dec.	398	1.00	398
	Total	3,243	1.10	3,578
-1965	Jan.	556	.98	547
	Feb.	515	1.02	525
	Mar.	556	1.01	562
	Apr.	1,222	1.03	1,259
	May	2,284	.95	2,170
	June	2,323	.88	2,044
	July	727	.48	349
	Aug.	71	.41	357
	Sept.	750	.40	300
	Oct.	659	.43	283
	Nov.	589	.47	277
	Dec.	531	.63	335
	Total	11,585	.78	9,008
-1966	Jan.	451	0.73	329
	Feb.	483	.76	367
	Mar.	622	.76	473
	Apr.	825	.77	635
	May	978	.72	704
	June	754	.71	535
	July	658	.66	434
	Aug.	682	.65	443
	Sept.	622	.66	411
	Oct.	551	.65	358
	Nov.	584	.66	385
	Dec.	529	.69	365
	Total	7,739	.70	5,439
-1967	Jan.	614	.76	467
	Feb.	534	.79	422
	Mar.	690	.89	614
	Apr.	788	1.03	812
	May	879	.93	817
	June	698	.99	691
	July	641	.81	519
	Aug.	693	.71	492
	Sept.	596	.75	447
	Oct.	415	.73	303
	Nov.	460	.76	350
	Dec.	552	.82	453
	Total	7,560	.84	6,387
-1968	Jan.	633	.93	589
	Feb.	464	.97	450
	Mar.	858	1.02	875
	Apr.	968	1.02	987
	May	943	1.05	990
	June	894	1.00	894
	July	827	.81	670
	Aug.	685	.70	480
	Sept.	635	.70	444
	Oct.	620	.69	428
	Nov.	616	.67	413
	Dec.	639	.79	505
	Total	8,782	.88	7,725
	Jan.			
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	Apr.			
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	Oct.			
	Nov.			
	Dec.			
	Total			

To obtain mg/l multiply T/AF by 735.

Table 12
Colorado River Basin
Historical Flow and Quality of Water Data
Colorado River at Lees Ferry, Arizona
(Annual Summary)

Units - 1000

Year	Flow (A.F.)	Concentration (T./A.F.)	Concentration (Mg./1)	T.D.S. (Tons)
1941	17,857	.70	514	12,481
1942	14,793	.63	466	9,381
1943	11,413	.73	539	8,375
1944	13,019	.65	481	8,525
1945	11,769	.72	531	8,501
1946	8,751	.84	617	7,346
1947	14,046	.68	498	9,513
1948	12,885	.66	487	8,531
1949	14,604	.68	501	9,954
1950	10,802	.75	551	8,098
1951	9,901	.79	581	7,833
1952	17,903	.64	468	11,396
1953	8,729	.86	630	7,485
1954	6,165	1.04	761	6,386
1955	6,966	.94	691	6,548
1956	8,658	.75	553	6,513
1957	18,700	.68	497	12,646
1958	13,139	.71	519	9,280
1959	7,061	.96	704	6,766
1960	8,790	.81	593	7,092
1961	7,314	.97	710	7,065
1962	14,439	.71	525	10,319
1963	1,384	1.27	934	1,758
1964	3,242	1.10	811	3,578
1965	11,585	.78	572	9,008
1966	7,739	.70	517	5,439
1967	7,560	.84	621	6,387
1968	8,782	.88	647	7,725
Total	297,990			223,929
Average	10,642	.75	552	7,997

Sampled quality record November 1942 to October 1945, October 1947 to December 1968; remainder by correlation.
Measured flow record entire period.

Table 13

Colorado River Basin

Historical Flow and Quality of Water Data

Colorado River near Grand Canyon, Arizona

Units - 1000

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
	Jan.	434	1.42	616
	Feb.	515	1.31	675
	Mar.	838	1.17	980
	Apr.	1,209	.87	1,052
	May	4,976	.50	2,488
	June	4,100	.45	1,845
-1941	July	1,753	.55	964
	Aug.	861	1.29	1,111
	Sept.	659	1.43	942
	Oct.	1,904	1.14	2,171
	Nov.	953	.98	934
	Dec.	594	1.22	725
Total		18,796	.77	14,503
	Jan.	430	1.40	602
	Feb.	435	1.33	579
	Mar.	653	1.25	816
	Apr.	2,763	.60	1,658
	May	3,163	.49	1,550
	June	4,241	.32	1,357
-1942	July	1,345	.59	794
	Aug.	486	1.15	559
	Sept.	294	1.67	491
	Oct.	356	1.67	575
	Nov.	386	1.67	645
	Dec.	373	1/1.50	560
Total		14,925	.68	10,186
	Jan.	347	1/1.49	517
	Feb.	351	1/1.48	519
	Mar.	580	1/1.26	731
	Apr.	1,417	1/ .83	1,176
	May	2,161	1/ .57	1,232
	June	2,676	1/ .49	1,311
-1943	July	1,459	1/ .60	875
	Aug.	834	1/1.17	976
	Sept.	494	1/1.40	692
	Oct.	408	1.69	690
	Nov.	477	1.47	701
	Dec.	420	1.46	613
Total		11,624	.86	10,033
	Jan.	298	1.61	480
	Feb.	363	1.23	446
	Mar.	551	1.41	777
	Apr.	1,099	.95	1,044
	May	3,206	.55	1,763
	June	4,144	.41	1,699
-1944	July	1,854	.52	964
	Aug.	456	1.14	520
	Sept.	251	1.61	404
	Oct.	362	1.78	644
	Nov.	401	1.54	558
	Dec.	345	1.59	549
Total		13,330	.75	9,948
	Jan.	356	1.55	552
	Feb.	381	1.48	564
	Mar.	472	1.41	666
	Apr.	804	1.01	812
	May	2,803	.52	1,458
	June	2,754	.48	1,322
-1945	July	1,732	.56	970
	Aug.	1,071	1.05	1,125
	Sept.	394	1.38	544
	Oct.	524	1.63	854
	Nov.	465	1.51	702
	Dec.	359	1.47	528
Total		12,115	.83	10,097
	Jan.	384	1.41	541
	Feb.	333	1.38	460
	Mar.	514	1.29	663
	Apr.	1,016	.94	955
	May	1,775	.53	941
	June	1,995	.54	1,077
-1946	July	784	.82	643
	Aug.	567	1.50	850
	Sept.	372	1.71	636
	Oct.	419	1.62	679
	Nov.	492	1.36	684
	Dec.	468	1.31	613
Total		9,119	.96	8,742
	Jan.	303	1.50	455
	Feb.	371	1.38	512
	Mar.	653	1.18	771
	Apr.	785	.92	722
	May	3,088	.48	1,482
	June	3,233	.48	1,552
-1947	July	1,953	.50	976
	Aug.	1,329	1.17	1,555
	Sept.	640	1.26	806
	Oct.	894	1.28	1,144
	Nov.	608	1.14	693
	Dec.	490	1.28	627
Total		14,347	.79	11,295
	Jan.	427	1.27	542
	Feb.	458	1.28	586
	Mar.	669	1.25	836
	Apr.	1,732	.74	1,282
	May	3,392	.45	1,526
	June	3,358	.40	1,343
-1948	July	1,009	.73	737
	Aug.	587	1.33	781
	Sept.	242	1.65	399
	Oct.	336	1.82	612
	Nov.	434	1.61	699
	Dec.	365	1.25	456
Total		13,009	.75	9,799
	Jan.	363	1.51	548
	Feb.	374	1.36	509
	Mar.	796	1.20	955
	Apr.	1,337	.92	1,230
	May	2,959	.48	1,420
	June	4,303	.48	2,065
-1949	July	2,128	.58	1,234
	Aug.	632	1.12	708
	Sept.	340	1.65	561
	Oct.	521	1.58	823
	Nov.	488	1.36	664
	Dec.	381	1.41	537
Total		[illegible]	.77	11,254
	Jan.	358	1.56	558
	Feb.	414	1.35	559
	Mar.	670	1.21	811
	Apr.	1,192	.88	1,049
	May	1,941	.59	1,145
	June	2,925	.47	1,375
-1950	July	1,401	.76	1,065
	Aug.	444	1.13	502
	Sept.	343	1.56	535
	Oct.	359	1.67	600
	Nov.	355	1.75	621
	Dec.	434	1.48	642
Total		10,836	.87	9,462
	Jan.	326	1.59	518
	Feb.	366	1.45	531
	Mar.	429	1.35	579
	Apr.	535	1.17	626
	May	1,552	.67	1,040
	June	2,800	.49	1,372
-1951	July	1,397	.57	796
	Aug.	833	1.18	983
	Sept.	452	1.46	660
	Oct.	425	1.67	710
	Nov.	466	1.61	750
	Dec.	353	1.61	568
Total		9,934	.92	9,133
	Jan.	593	1.28	759
	Feb.	396	1.42	562
	Mar.	435	1.46	635
	Apr.	2,209	.84	1,855
	May	5,062	.52	2,632
	June	5,203	.46	2,393
-1952	July	1,590	.65	1,033
	Aug.	833	1.18	983
	Sept.	596	1.43	852
	Oct.	393	1.52	597
	Nov.	396	1.64	649
	Dec.	400	1.58	632
Total		18,806	.75	13,582
	Jan.	408	1.46	596
	Feb.	378	1.42	537
	Mar.	478	1.35	645
	Apr.	533	1.21	645
	May	989	.87	860
	June	2,932	.47	1,378
-1953	July	980	.76	745
	Aug.	703	1.30	914
	Sept.	290	1.73	502
	Oct.	325	1.88	611
	Nov.	428	1.63	698
	Dec.	360	1.56	562
Total		8,804	.99	8,693
	Jan.	333	1.58	526
	Feb.	353	1.40	494
	Mar.	424	1.34	568
	Apr.	566	1.11	628
	May	1,211	.68	823
	June	798	.68	543
-1954	July	669	.95	636
	Aug.	349	1.32	461
	Sept.	415	1.67	693
	Oct.	526	1.52	800
	Nov.	360	1.47	529
	Dec.	296	1.60	474
Total		6,300	1.14	7,175
	Jan.	261	1.70	444
	Feb.	269	1.50	404
	Mar.	586	1.35	791
	Apr.	621	1.15	714
	May	1,515	.59	894
	June	1,596	.55	878
-1955	July	618	.77	476
	Aug.	668	1.39	929
	Sept.	265	1.63	432
	Oct.	236	1.84	434
	Nov.	298	1/1.88	560
	Dec.	354	1/1.52	538
Total		7,287	1.03	7,494
	Jan.	398	1/1.42	565
	Feb.	310	1.30	403
	Mar.	511	1.21	618
	Apr.	878	.82	720
	May	2,125	.49	1,041
	June	2,584	.45	1,163
-1956	July	598	.82	490
	Aug.	383	1.31	502
	Sept.	185	1.58	292
	Oct.	202	1.86	376
	Nov.	325	1.69	549
	Dec.	274	1.66	455
Total		8,773	.82	7,174
	Jan.	343	1.45	497
	Feb.	370	1.37	507
	Mar.	541	1.26	682
	Apr.	812	.93	755
	May	2,501	.57	1,426
	June	5,541	.40	2,216
-1957	July	4,033	.40	1,613
	Aug.	1,672	.88	1,471
	Sept.	884	1.13	999
	Oct.	784	1.46	1,144
	Nov.	892	1.42	1,266
	Dec.	537	1.28	687
Total		18,910	.70	13,263
	Jan.	415	1.31	544
	Feb.	536	1.24	665
	Mar.	749	1.13	846
	Apr.	1,580	.77	1,220
	May	3,900	.45	1,755
	June	3,763	.41	1,542
-1958	July	683	.91	622
	Aug.	337	1/1.31	440
	Sept.	379	1/1.32	500
	Oct.	346	1/1.53	530
	Nov.	385	1/1.53	590
	Dec.	388	1/1.55	600
Total		13,461	.73	9,854

To obtain mg/l multiply T/AF by 735.

1/ Correlated.

Table 13

Colorado River Basin

Historical Flow and Quality of Water Data

Colorado River near Grand Canyon, Arizona

Units - 1000

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
	Jan.	334	1/1.56	520
	Feb.	326	1/1.53	500
	Mar.	365	1/1.53	560
-1959	Apr.	423	1.27	537
	May	1,011	.78	789
	June	1,804	.53	956
	July	795	.69	549
	Aug.	488	1.50	731
	Sept.	271	1.82	493
	Oct.	528	1.47	777
	Nov.	569	1.25	712
	Dec.	394	1.33	524
Total		7,308	1.05	7,648
	Jan.	348	1.41	490
	Feb.	353	1.40	495
	Mar.	820	1.15	942
-1960	Apr.	1,650	.63	1,036
	May	1,580	.55	870
	June	2,212	.46	1,011
	July	678	.73	497
	Aug.	233	1.42	331
	Sept.	218	1.92	418
	Oct.	382	1.81	692
	Nov.	380	1.59	603
	Dec.	300	1.49	448
Total		9,154	.86	7,833
	Jan.	291	1.58	460
	Feb.	353	1.39	490
	Mar.	379	1.40	530
-1961	Apr.	587	1.04	608
	May	1,147	.66	760
	June	1,692	.47	788
	July	417	.98	409
	Aug.	374	1.76	658
	Sept.	748	1.82	1,360
	Oct.	772	1.23	949
	Nov.	570	1.23	701
	Dec.	409	1.32	539
Total		7,739	1.07	8,252
	Jan.	369	1.35	498
	Feb.	832	1.02	847
	Mar.	610	1.19	726
-1962	Apr.	2,467	.70	1,730
	May	3,716	.45	1,654
	June	2,850	.46	1,318
	July	1,821	.57	1,031
	Aug.	512	1.03	526
	Sept.	318	1.58	502
	Oct.	557	1.57	877
	Nov.	443	1.34	592
	Dec.	344	1.50	516
Total		14,839	.73	10,817
	Jan.	182	1.84	334
	Feb.	374	1.33	496
	Mar.	203	1.37	279
-1963	Apr.	72	1.56	112
	May	79	1.49	118
	June	148	1.09	162
	July	108	1.14	123
	Aug.	112	1.29	145
	Sept.	122	1.43	175
	Oct.	77	1.39	107
	Nov.	76	1.39	106
	Dec.	77	1.74	134
Total		1,630	1.41	2,291
	Jan.	79	1.75	138
	Feb.	245	1.52	373
	Mar.	382	1.47	562
-1964	Apr.	796	1.33	1,058
	May	356	1.36	485
	June	77	1.65	127
	July	84	1.75	147
	Aug.	287	1.31	376
	Sept.	191	1.05	200
	Oct.	298	.77	230
	Nov.	371	.87	323
	Dec.	416	1.04	431
Total		3,582	1.24	4,450

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
	Jan.	608	1.06	644
	Feb.	539	1.09	588
	Mar.	568	1.09	619
	Apr.	1,251	1.04	1,301
	May	2,282	1.03	2,350
	June	2,282	.89	2,038
-1965	July	724	.59	427
	Aug.	879	.86	755
	Sept.	767	.51	391
	Oct.	675	.51	344
	Nov.	612	.53	322
	Dec.	586	.69	406
Total		11,773	.86	10,185
	Jan.	529	0.79	418
	Feb.	524	.87	455
	Mar.	718	.81	582
	Apr.	865	.81	700
	May	1,011	.79	799
	June	789	.77	609
-1966	July	698	.75	523
	Aug.	694	.68	471
	Sept.	623	.75	468
	Oct.	567	.74	419
	Nov.	589	.71	418
	Dec.	620	.76	471
Total		8,230	.77	6,33
	Jan.	648	.84	544
	Feb.	564	.86	485
	Mar.	704	.97	683
	Apr.	801	1.09	873
	May	861	1.00	861
	June	711	1.02	725
-1967	July	693	.92	638
	Aug.	786	.82	644
	Sept.	713	.90	642
	Oct.	459	.86	395
	Nov.	495	.83	411
	Dec.	597	.90	537
Total		8,032	.93	7,438
	Jan.	658	1.01	664
	Feb.	534	1.04	555
	Mar.	900	1.03	927
	Apr.	1,076	1.02	1,100
	May	976	1.11	1,083
	June	925	1.03	953
-1968	July	865	.93	804
	Aug.	775	.81	628
	Sept.	675	.80	540
	Oct.	647	.79	511
	Nov.	675	.80	540
	Dec.	665	.77	512
Total		9,373	.94	8,817
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
Total				
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	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
Total				

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
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	Nov.			
	Dec.			
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	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
Total				

To obtain mg/l multiply T/AF by 735.

Table 13

Colorado River Basin

Historical Flow and Quality of Water Data

Colorado River near Grand Canyon, Arizona

(Annual Summary)

Units - 1000

Year	Flow (A.F.)	Concentration (T./A.F.)	Concentration (Mg./l)	T.D.S. (Tons)
1941	18,796	0.77	567	14,503
1942	14,925	.68	502	10,186
1943	11,624	.86	634	10,033
1944	13,330	.75	549	9,948
1945	12,115	.83	613	10,097
1946	9,119	.96	705	8,742
1947	14,347	.79	579	11,295
1948	13,009	.75	554	9,799
1949	14,622	.77	566	11,254
1950	10,836	.87	642	9,462
1951	9,934	.92	676	9,133
1952	18,106	.75	551	13,582
1953	8,804	.99	726	8,693
1954	6,300	1.14	837	7,175
1955	7,287	1.03	756	7,494
1956	8,773	.82	601	7,174
1957	18,910	.70	516	13,263
1958	13,461	.73	538	9,854
1959	7,308	1.05	769	7,648
1960	9,154	.86	629	7,833
1961	7,739	1.07	784	8,252
1962	14,839	.73	536	10,817
1963	1,630	1.41	1,030	2,291
1964	3,582	1.24	913	4,450
1965	11,773	.86	636	10,185
1966	8,230	.77	566	6,333
1967	8,032	.93	681	7,438
1968	9,373	.94	691	8,817
Total	305,958			255,751
Average	10,927	.84	614	9,134

Table 14
Colorado River Basin
Historical Flow and Quality of Water Data
Virgin River at Littlefield, Arizona

Units - 1000

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
	Jan.	15	2.39	35
	Feb.	31	1.97	61
	Mar.	62	.82	51
	Apr.	62	.84	52
	May	131	.46	60
	June	19	1.75	34
-1941	July	22	2.45	54
	Aug.	20	3.02	62
	Sept.	6	3.29	18
	Oct.	23	3.22	74
	Nov.	19	2.26	43
	Dec.	17	2.28	39
Total		427	1.37	583
	Jan.	20	2.25	44
	Feb.	16	2.26	35
	Mar.	20	1.88	38
	Apr.	50	1.01	51
	May	28	1.56	44
	June	5	3.15	16
-1942	July	4	3.31	14
	Aug.	9	3.29	21
	Sept.	4	3.31	13
	Oct.	9	3.41	31
	Nov.	10	2.78	29
	Dec.	11	2.72	31
Total		186	2.01	375
	Jan.	18	2.32	42
	Feb.	21	2.14	45
	Mar.	36	1.28	47
	Apr.	34	1.36	46
	May	11	2.27	26
	June	4	3.35	13
-1943	July	4	3.31	14
	Aug.	13	3.35	42
	Sept.	6	3.46	20
	Oct.	9	3.40	30
	Nov.	10	2.79	28
	Dec.	13	2.51	32
Total		179	2.15	385
	Jan.	13	2.47	33
	Feb.	15	2.31	35
	Mar.	26	1.64	42
	Apr.	25	1.66	42
	May	49	1.05	51
	June	11	2.32	25
-1944	July	4	3.32	13
	Aug.	4	3.31	13
	Sept.	4	3.31	14
	Oct.	5	3.30	16
	Nov.	13	2.48	32
	Dec.	12	2.65	31
Total		181	1.92	347
	Jan.	11	2.68	30
	Feb.	17	2.15	38
	Mar.	20	1.87	38
	Apr.	20	1.83	36
	May	25	1.55	39
	June	5	3.22	15
-1945	July	5	3.31	15
	Aug.	26	3.06	79
	Sept.	8	3.19	25
	Oct.	20	3.14	62
	Nov.	10	2.75	29
	Dec.	14	2.47	35
Total		181	2.43	441
	Jan.	13	2.48	32
	Feb.	10	2.74	27
	Mar.	10	2.63	28
	Apr.	12	2.49	29
	May	5	3.31	15
	June	4	3.32	13
-1946	July	6	3.40	21
	Aug.	13	3.17	42
	Sept.	4	3.31	13
	Oct.	37	2.18	81
	Nov.	33	1.85	61
	Dec.	22	2.12	47
Total		169	2.42	409

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
	Jan.	15	2.34	35
	Feb.	12	2.46	30
	Mar.	13	2.32	31
	Apr.	16	2.17	34
	May	17	1.98	33
	June	4	3.31	14
-1947	July	5	3.30	16
	Aug.	14	2.97	41
	Sept.	4	3.31	14
	Oct.	8	3.34	27
	Nov.	9	2.89	27
	Dec.	14	2.46	34
Total		131	2.56	336
	Jan.	11	2.76	29
	Feb.	12	2.47	30
	Mar.	13	2.42	31
	Apr.	20	1.87	37
	May	10	2.47	25
	June	4	3.32	14
-1948	July	4	3.31	14
	Aug.	5	3.31	18
	Sept.	5	3.39	20
	Oct.	6	3.34	20
	Nov.	10	2.87	27
	Dec.	10	2.85	29
Total		111	2.65	294
	Jan.	13	2.52	32
	Feb.	14	2.42	35
	Mar.	18	2.07	36
	Apr.	30	1.43	44
	May	28	1.53	43
	June	12	2.11	25
-1949	July	4	3.19	14
	Aug.	4	3.20	13
	Sept.	7	3.27	23
	Oct.	9	3.07	26
	Nov.	11	2.68	29
	Dec.	13	2.51	34
Total		163	2.17	354
	Jan.	15	2.20	33
	Feb.	16	2.00	32
	Mar.	14	2.26	31
	Apr.	15	2.05	31
	May	6	2.87	19
	June	4	3.28	13
-1950	July	12	3.38	40
	Aug.	6	3.43	19
	Sept.	6	3.35	20
	Oct.	5	3.40	17
	Nov.	9	3.14	28
	Dec.	10	2.91	30
Total		118	2.65	313
	Jan.	11	2.77	30
	Feb.	8	2.84	22
	Mar.	8	2.83	23
	Apr.	7	3.17	22
	May	10	2.74	27
	June	4	3.37	12
-1951	July	6	3.34	20
	Aug.	16	3.27	55
	Sept.	6	3.20	20
	Oct.	7	3.24	22
	Nov.	9	2.94	26
	Dec.	20	2.42	49
Total		112	2.93	328
	Jan.	21	2.34	49
	Feb.	11	2.52	28
	Mar.	27	1.74	48
	Apr.	80	.76	60
	May	71	.68	49
	June	12	1.75	21
-1952	July	4	3.27	14
	Aug.	5	3.43	18
	Sept.	6	3.34	20
	Oct.	6	3.40	20
	Nov.	10	2.84	29
	Dec.	14	2.53	34
Total		267	1.46	390

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
	Jan.	14	2.36	32
	Feb.	9	2.70	24
	Mar.	7	2.98	21
	Apr.	6	3.27	20
	May	5	3.27	16
	June	4	3.34	14
-1953	July	8	3.46	28
	Aug.	13	3.04	40
	Sept.	4	3.38	13
	Oct.	7	3.41	24
	Nov.	10	3.07	29
	Dec.	11	2.83	31
Total		98	3.00	292
	Jan.	15	2.49	37
	Feb.	12	2.36	29
	Mar.	17	1.98	33
	Apr.	23	1.64	38
	May	10	2.35	23
	June	5	3.36	18
-1954	July	8	3.42	26
	Aug.	10	3.44	[illegible]
	Sept.	9	3.56	32
	Oct.	9	3.48	30
	Nov.	9	3.13	29
	Dec.	14	2.71	36
Total		146	2.61	[illegible]
	Jan.	12	2.60	31
	Feb.	12	2.51	30
	Mar.	11	2.53	27
	Apr.	6	3.14	19
	May	5	3.18	16
	June	4	3.34	13
-1955	July	10	3.61	37
	Aug.	40	3.69	149
	Sept.	5	3.26	15
	Oct.	5	3.51	19
	Nov.	10	3.05	31
	Dec.	13	2.60	34
Total		133	3.16	421
	Jan.	15	2.53	38
	Feb.	11	2.59	29
	Mar.	8	2.87	22
	Apr.	6	3.13	18
	May	4	3.23	15
	June	4	3.34	15
-1956	July	8	3.54	27
	Aug.	4	3.35	13
	Sept.	4	3.35	12
	Oct.	4	3.39	14
	Nov.	6	3.52	21
	Dec.	8	3.29	25
Total		82	3.05	249
	Jan.	12	2.77	33
	Feb.	14	2.32	32
	Mar.	10	2.64	26
	Apr.	6	2.99	18
	May	15	2.04	31
	June	9	2.85	25
-1957	July	4	3.31	13
	Aug.	9	3.41	31
	Sept.	4	3.27	12
	Oct.	14	3.02	44
	Nov.	21	2.45	51
	Dec.	15	2.04	31
Total		133	2.61	347
	Jan.	10	2.49	24
	Feb.	19	1.83	35
	Mar.	41	1.43	59
	Apr.	64	1.02	65
	May	69	1.05	73
	June	7	2.29	16
-1958	July	6	3.17	19
	Aug.	5	3.22	18
	Sept.	22	3.13	70
	Oct.	8	3.16	24
	Nov.	11	2.62	28
	Dec.	10	3.67	36
Total		272	1.68	457

To obtain mg/l multiply T/AF by 735.

Table 14
Colorado River Basin
Historical Flow and Quality of Water Data

Virgin River at Littlefield, Arizona

Units - 1000

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
-1959	Jan.	10	2.58	27
	Feb.	13	2.30	31
	Mar.	9	2.67	24
	Apr.	4	3.05	13
	May	4	3.07	13
	June	4	3.24	12
	July	4	3.32	13
	Aug.	12	3.35	40
	Sept.	4	3.20	13
	Oct.	5	3.30	15
	Nov.	13	2.90	36
	Dec.	9	2.69	23
	Total	91	2.87	260
-1960	Jan.	11	2.48	28
	Feb.	10	2.38	24
	Mar.	10	2.45	24
	Apr.	6	2.91	17
	May	5	3.03	14
	June	3	3.16	10
	July	4	3.18	12
	Aug.	3	3.20	11
	Sept.	6	3.51	20
	Oct.	6	3.05	19
	Nov.	12	2.80	35
	Dec.	8	2.71	22
	Total	84	2.79	236
-1961	Jan.	8	2.76	21
	Feb.	7	2.86	20
	Mar.	8	2.84	23
	Apr.	4	3.11	14
	May	4	3.14	12
	June	4	3.14	12
	July	8	3.22	27
	Aug.	17	3.58	60
	Sept.	22	3.32	73
	Oct.	5	3.41	19
	Nov.	8	3.07	23
	Dec.	13	2.69	34
	Total	108	3.14	338
-1962	Jan.	10	2.73	28
	Feb.	30	1.65	50
	Mar.	17	2.09	35
	Apr.	33	1.21	40
	May	9	2.24	19
	June	4	3.32	12
	July	4	3.29	13
	Aug.	3	3.46	11
	Sept.	7	3.28	24
	Oct.	7	3.32	21
	Nov.	6	3.18	20
	Dec.	7	2.75	20
	Total	137	2.14	293
-1963	Jan.	9	2.54	23
	Feb.	9	2.56	23
	Mar.	6	3.14	19
	Apr.	4	3.43	15
	May	4	3.41	13
	June	3	3.44	11
	July	3	3.48	12
	Aug.	11	3.33	36
	Sept.	14	3.54	48
	Oct.	5	3.32	18
	Nov.	10	3.00	28
	Dec.	7	2.96	20
	Total	85	3.14	266
-1964	Jan.	7	2.96	20
	Feb.	7	2.88	21
	Mar.	7	2.99	20
	Apr.	13	2.22	28
	May	11	2.22	24
	June	3	3.50	10
	July	4	3.63	14
	Aug.	14	3.81	53
	Sept.	3	3.63	11
	Oct.	3	3.58	12
	Nov.	6	3.32	22
	Dec.	9	2.98	26
	Total	87	3.01	261

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
-1965	Jan.	9	2.78	25
	Feb.	8	2.75	22
	Mar.	8	2.62	21
	Apr.	30	2.00	60
	May	23	1.52	35
	June	9	2.11	19
	July	3	3.67	11
	Aug.	5	3.40	17
	Sept.	6	3.00	18
	Oct.	6	3.00	18
	Nov.	21	1.90	40
	Dec.	26	1.58	41
	Total	15[illegible]	2.12	327
-1966	Jan.	13	2.31	30
	Feb.	11	2.45	27
	Mar.	14	1.50	29
	Apr.	17	1.70	29
	May	6	3.00	18
	June	3	4.00	12
	July	3	4.00	12
	Aug.	3	3.67	11
	Sept.	4	3.50	14
	Oct.	6	3.33	20
	Nov.	9	2.78	25
	Dec.	73	1.99	145
	Total	162	2.30	372
-1967	Jan.	13	2.66	34
	Feb.	9	2.67	25
	Mar.	10	2.76	29
	Apr.	11	2.63	30
	May	20	1.88	37
	June	7	2.80	19
	July	4	3.57	14
	Aug.	7	3.32	25
	Sept.	14	3.41	46
	Oct.	7	3.13	21
	Nov.	9	2.71	25
	Dec.	13	2.49	32
	Total	124	2.72	337
-1968	Jan.	13	2.60	33
	Feb.	15	2.19	32
	Mar.	12	2.16	27
	Apr.	15	2.03	30
	May	17	1.80	30
	June	5	2.81	13
	July	6	3.52	20
	Aug.	14	3.09	45
	Sept.	3	3.60	12
	Oct.	6	3.41	20
	Nov.	7	3.05	22
	Dec.	11	2.79	30
	Total	124	2.53	314
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			

To obtain mg/l multiply T/AF by 735.

Table 14
Colorado River Basin
Historical Flow and Quality of Water Data
Virgin River at Littlefield, Arizona
(Annual Summary)

Units - 1000

Year	Flow	Concentration		T.D.S.
	(A.F.)	(T./A.F.)	(Mg./1)	(Tons)
1941	427	1.37	1,000	583
1942	186	2.01	1,480	375
1943	179	2.15	1,580	385
1944	181	1.92	1,410	347
1945	181	2.43	1,790	441
1946	169	2.42	1,780	409
1947	131	2.56	1,890	336
1948	111	2.65	1,950	294
1949	163	2.17	1,600	354
1950	118	2.65	1,950	313
1951	112	2.93	2,150	328
1952	267	1.46	1,070	390
1953	98	3.00	2,190	292
1954	140	2.61	1,920	365
1955	133	3.16	2,330	421
1956	82	3.05	2,230	249
1957	133	2.61	1,920	347
1958	272	1.68	1,230	457
1959	91	2.87	2,100	260
1960	84	2.79	2,060	236
1961	108	3.14	2,300	338
1962	137	2.14	1,570	293
1963	85	3.14	2,300	266
1964	87	3.01	2,200	261
1965	154	2.12	1,560	327
1966	162	2.30	1,690	372
1967	124	2.72	1,980	337
1968	124	2.53	1,860	314
Total	4,239			9,690
Average	151	2.29	1,680	346

Table 15

Colorado River Basin

Historical Flow and Quality of Water Data

Colorado River below Hoover Dam, Arizona - Nevada

Units - 1000

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
-1941	Jan.	589	1.08	636
	Feb.	500	1.11	555
	Mar.	552	1.10	607
	Apr.	518	1.08	560
	May	1,435	1.08	1,550
	June	1,810	1.07	1,935
	July	951	1.06	1,007
	Aug.	1,429	.97	1,386
	Sept.	1,576	.94	1,481
	Oct.	1,641	.94	1,543
	Nov.	1,817	.93	1,690
	Dec.	2,071	.94	1,947
	Total	14,889	1.00	14,897
-1942	Jan.	2,011	1.00	2,011
	Feb.	1,550	.99	1,535
	Mar.	1,425	1.00	1,425
	Apr.	1,301	1.00	1,301
	May	1,343	1.00	1,343
	June	1,561	1.01	1,577
	July	1,285	.99	1,272
	Aug.	846	.99	838
	Sept.	1,025	.98	1,005
	Oct.	1,163	.95	1,105
	Nov.	1,095	.90	986
	Dec.	1,157	.85	983
	Total	15,762	.98	15,381
-1943	Jan.	1,109	.87	965
	Feb.	823	.89	732
	Mar.	971	.94	913
	Apr.	915	.95	869
	May	1,029	.94	967
	June	1,040	.93	967
	July	1,109	.91	1,009
	Aug.	1,042	.92	959
	Sept.	1,042	.91	948
	Oct.	1,179	.90	1,061
	Nov.	1,179	.86	1,014
	Dec.	1,277	.86	1,098
	Total	12,715	.90	11,502
-1944	Jan.	1,303	.88	1,147
	Feb.	1,269	.97	1,231
	Mar.	1,307	.96	1,254
	Apr.	1,170	.97	1,135
	May	1,216	.98	1,192
	June	1,097	.95	1,042
	July	1,111	.93	1,033
	Aug.	1,211	.92	1,113
	Sept.	1,132	.89	1,007
	Oct.	1,226	1/.94	1,152
	Nov.	1,186	1/.99	1,174
	Dec.	1,199	.94	1,127
	Total	14,427	.94	13,607
-1945	Jan.	1,239	.93	1,152
	Feb.	1,100	1/.96	1,056
	Mar.	1,250	2/.96	1,200
	Apr.	1,042	1/.95	990
	May	1,068	1/.90	961
	June	1,014	2/.91	923
	July	861	.92	792
	Aug.	885	1/.93	823
	Sept.	869	1/.90	782
	Oct.	1,080	1/.88	950
	Nov.	1,042	1/.90	938
	Dec.	1,062	1/.89	945
	Total	12,512	.92	11,512
-1946	Jan.	1,116	.87	971
	Feb.	1,047	1/.95	994
	Mar.	1,004	.88	884
	Apr.	*872	.89	*776
	May	903	1/.96	867
	June	817	1/.92	752
	July	838	.90	754
	Aug.	751	1/.91	683
	Sept.	759	2/.91	691
	Oct.	857	1/.92	788
	Nov.	762	2/.91	693
	Dec.	859	1/.90	773
	Total	*10,585	.91	*9,626
-1947	Jan.	984	0.90	886
	Feb.	886	.91	806
	Mar.	956	.92	879
	Apr.	859	1/.99	850
	May	951	1/1.03	979
	June	919	1/.95	873
	July	925	.96	888
	Aug.	865	1/.92	796
	Sept.	843	2/.92	776
	Oct.	828	1/.92	762
	Nov.	880	2/.92	810
	Dec.	1,063	1/.92	978
	Total	10,959	.94	10,283
-1948	Jan.	1,169	2/.93	1,087
	Feb.	1,138	1/.93	1,058
	Mar.	1,150	1/.93	1,070
	Apr.	1,202	1/.97	1,166
	May	1,142	1/.93	1,062
	June	1,076	1/.88	947
	July	1,156	1/.86	994
	Aug.	968	2/.86	833
	Sept.	981	1/.85	834
	Oct.	917	1/.80	734
	Nov.	1,028	.88	905
	Dec.	1,124	1/.91	1,023
	Total	13,051	.90	11,713
-1949	Jan.	1,212	.83	1,006
	Feb.	1,214	1/.84	1,020
	Mar.	1,291	1/.85	1,097
	Apr.	1,178	1/.86	1,013
	May	1,026	1/.83	852
	June	986	.87	858
	July	1,020	.84	857
	Aug.	1,062	.80	850
	Sept.	1,141	.78	890
	Oct.	1,176	.75	882
	Nov.	1,022	1/.83	848
	Dec.	1,238	.87	1,077
	Total	13,566	.83	11,250
-1950	Jan.	1,277	.83	1,060
	Feb.	1,132	.81	917
	Mar.	1,246	.85	1,059
	Apr.	1,089	.85	926
	May	1,120	1/.84	941
	June	960	1/.83	797
	July	982	.79	776
	Aug.	872	1/.82	715
	Sept.	824	1/.79	651
	Oct.	848	.89	755
	Nov.	815	.88	717
	Dec.	851	.86	732
	Total	12,016	.84	10,046
-1951	Jan.	928	.87	807
	Feb.	756	.87	658
	Mar.	860	.91	783
	Apr.	796	.93	740
	May	898	.92	826
	June	691	.91	629
	July	783	.92	720
	Aug.	907	.93	844
	Sept.	848	.92	780
	Oct.	756	.93	703
	Nov.	818	.93	761
	Dec.	829	.91	754
	Total	9,870	.91	9,005
-1952	Jan.	1,070	.90	963
	Feb.	1,212	.93	1,127
	Mar.	1,371	.94	1,289
	Apr.	1,385	.94	1,302
	May	1,532	.94	1,440
	June	1,432	.91	1,303
	July	1,304	.83	1,082
	Aug.	1,307	.79	1,033
	Sept.	1,359	.73	992
	Oct.	1,291	.69	891
	Nov.	1,215	.66	802
	Dec.	1,338	.88	1,177
	Total	15,816	.85	13,401
-1953	Jan.	1,227	0.93	1,141
	Feb.	1,043	.91	949
	Mar.	1,046	.93	973
	Apr.	971	.94	913
	May	998	.91	908
	June	819	.89	729
	July	897	.87	780
	Aug.	968	.87	842
	Sept.	968	.86	832
	Oct.	802	.86	690
	Nov.	749	.86	644
	Dec.	814	.85	692
	Total	11,302	.89	10,093
-1954	Jan.	836	.88	736
	Feb.	721	.94	678
	Mar.	911	.95	865
	Apr.	975	.94	916
	May	1,101	.93	1,024
	June	929	.94	873
	July	1,027	.94	965
	Aug.	888	.97	861
	Sept.	933	.97	905
	Oct.	776	.94	729
	Nov.	676	.95	642
	Dec.	741	.97	719
	Total	10,514	.94	9,913
-1955	Jan.	725	.99	718
	Feb.	705	1.04	733
	Mar.	906	1.08	978
	Apr.	882	1.11	979
	May	928	1.12	1,039
	June	680	1.12	762
	July	847	1.11	940
	Aug.	789	1.12	884
	Sept.	622	1.11	690
	Oct.	526	1.12	589
	Nov.	487	1.12	545
	Dec.	492	1.09	536
	Total	8,589	1.09	9,393
-1956	Jan.	581	1.09	635
	Feb.	499	1.10	549
	Mar.	769	1.12	861
	Apr.	840	1.14	958
	May	748	1.15	860
	June	784	1.17	917
	July	782	1.19	931
	Aug.	696	1.17	814
	Sept.	610	1.15	702
	Oct.	490	1.16	568
	Nov.	554	1.12	620
	Dec.	457	1.10	503
	Total	7,812	1.14	8,918
-1957	Jan.	534	1.07	571
	Feb.	470	1.08	508
	Mar.	739	1.11	820
	Apr.	890	1.09	970
	May	769	1.07	823
	June	828	1.06	878
	July	786	1.05	825
	Aug.	786	1.03	810
	Sept.	785	1.02	801
	Oct.	697	1.02	711
	Nov.	958	.99	948
	Dec.	1,081	.94	1,016
	Total	9,323	1.04	9,681
-1958	Jan.	1,245	.90	1,120
	Feb.	846	.94	795
	Mar.	1,435	.90	1,292
	Apr.	1,473	.88	1,296
	May	1,115	.84	937
	June	819	.85	696
	July	894	.85	760
	Aug.	911	.83	756
	Sept.	792	.83	657
	Oct.	728	.82	597
	Nov.	746	.82	612
	Dec.	873	.83	725
	Total	11,877	.86	10,243

To obtain mg/l multiply T/AF by 735.
*Revised
1/ Estimated or partially estimated.
2/ Average of adjacent values.

Table 15

Colorado River Basin

Historical Flow and Quality of Water Data

Colorado River below Hoover Dam, Arizona-Nevada

Units-1000

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
-1959	Jan.	795	0.85	676
	Feb.	648	.83	537
	Mar.	827	.88	728
	Apr.	916	.91	834
	May	949	.86	816
	June	760	.85	646
	July	848	.84	713
	Aug.	894	.83	742
	Sept.	773	.81	626
	Oct.	693	.82	568
	Nov.	607	.81	492
	Dec.	572	.81	463
	Total	9,282	.84	7,841
-1960	Jan.	629	.86	541
	Feb.	512	.89	456
	Mar.	710	.89	632
	Apr.	909	.93	845
	May	856	.93	796
	June	1,015	.92	934
	July	984	.89	876
	Aug.	959	.93	892
	Sept.	806	.93	749
	Oct.	556	.92	512
	Nov.	489	.92	450
	Dec.	572	.92	526
	Total	8,997	.91	8,209
-1961	Jan.	591	.93	549
	Feb.	577	.94	543
	Mar.	936	.95	889
	Apr.	904	.97	877
	May	943	.95	896
	June	842	.94	791
	July	822	.94	772
	Aug.	739	.96	709
	Sept.	690	.96	663
	Oct.	539	.93	502
	Nov.	517	.94	486
	Dec.	486	.95	462
	Total	8,586	.95	8,139
-1962	Jan.	482	.93	448
	Feb.	497	1/.94	467
	Mar.	798	1/.94	750
	Apr.	902	1/.95	857
	May	887	1.00	887
	June	799	1/.94	751
	July	824	1/.91	750
	Aug.	857	1/.87	746
	Sept.	716	1.00	716
	Oct.	634	1/.86	545
	Nov.	613	1/.90	552
	Dec.	606	1/.93	564
	Total	8,615	1/.93	8,033
-1963	Jan.	482	.99	478
	Feb.	575	1/.97	558
	Mar.	871	1/.95	828
	Apr.	865	1/.94	813
	May	911	.93	847
	June	764	1/.92	702
	July	908	1/.91	826
	Aug.	857	.90	771
	Sept.	724	.89	645
	Oct.	527	.90	475
	Nov.	464	.89	413
	Dec.	585	.90	526
	Total	8,533	1/.92	7,882
-1964	Jan.	633	.93	589
	Feb.	583	.94	548
	Mar.	800	.95	760
	Apr.	859	.98	842
	May	844	.98	827
	June	719	.99	712
	July	866	.98	849
	Aug.	731	.99	724
	Sept.	623	.99	616
	Oct.	591	1.01	596
	Nov.	445	1.02	454
	Dec.	469	1.06	497
	Total	8,163	.98	8,014

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
-1965	Jan.	489	1.08	528
	Feb.	498	1.09	543
	Mar.	786	1.15	903
	Apr.	698	1.14	796
	May	872	1.14	994
	June	786	1.08	848
	July	815	1.08	880
	Aug.	817	1.11	907
	Sept.	655	1.12	734
	Oct.	535	1.05	562
	Nov.	418	1.03	430
	Dec.	423	1.06	449
	Total	7,792	1.10	8,574
-1966	Jan.	252	1.03	260
	Feb.	436	1.02	445
	Mar.	785	1.05	824
	Apr.	846	1.05	888
	May	887	1.03	914
	June	783	1.06	831
	July	889	1.01	897
	Aug.	839	.98	822
	Sept.	672	1.00	672
	Oct.	467	.96	448
	Nov.	473	.93	440
	Dec.	448	.93	416
	Total	7,777	1.01	7,857
-1967	Jan.	500	.94	470
	Feb.	574	.92	528
	Mar.	847	.91	771
	Apr.	771	.90	694
	May	889	.93	827
	June	782	.94	735
	July	832	.90	749
	Aug.	755	.90	679
	Sept.	494	.93	459
	Oct.	576	.93	536
	Nov.	556	.91	506
	Dec.	356	.92	328
	Total	7,932	.92	7,282
-1968	Jan.	396	.94	372
	Feb.	496	.92	456
	Mar.	850	.93	791
	Apr.	883	.93	821
	May	853	.95	810
	June	752	.93	699
	July	757	.94	712
	Aug.	693	.97	672
	Sept.	663	.97	643
	Oct.	486	.98	476
	Nov.	457	.99	452
	Dec.	553	1.00	553
	Total	7,839	.95	7,457
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			

To obtain mg/l multiply T/AF by 735.

1/Estimated or partially estimated.

Table 15
Colorado River Basin
Historical Flow and Quality of Water Data
Colorado River below Hoover Dam, Arizona, Nevada

(Annual Summary)

Units - 1000

Year	Flow (A.F.)	Concentration (T./A.F.)	Concentration (Mg./l)	T.D.S. (Tons)
1941	14,889	1.00	735	14,897
1942	15,762	.98	717	15,381
1943	12,715	.90	665	11,502
1944	14,427	.94	693	13,607
1945	12,512	.92	676	11,512
1946	10,585	.91	668	9,626
1947	10,959	.94	690	10,283
1948	13,051	.90	660	11,713
1949	13,566	.83	610	11,250
1950	12,016	.84	614	10,046
1951	9,870	.91	671	9,005
1952	15,816	.85	623	13,401
1953	11,302	.89	656	10,093
1954	10,514	.94	693	9,913
1955	8,589	1.09	804	9,393
1956	7,812	1.14	839	8,918
1957	9,323	1.04	763	9,681
1958	11,877	.86	634	10,243
1959	9,282	.84	621	7,841
1960	8,997	.91	671	8,209
1961	8,586	.95	697	8,139
1962	8,615	.93	685	8,033
1963	8,533	.92	677	7,882
1964	8,163	.98	722	8,014
1965	7,792	1.10	809	8,574
1966	7,777	1.01	743	7,857
1967	7,932	.92	675	7,282
1968	7,839	.95	699	7,457
Total	299,10[illegible]			279,752
Average	10,682	.94	687	9,991

Measured flow record entire period.

Table 16

Colorado River Basin

Historical Flow and Quality of Water Data

Colorado River below Parker Dam, Arizona-California

Units-1000

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
	Jan.	627	1.09	683
	Feb.	561	1.12	628
	Mar.	750	1.11	833
	Apr.	608	1.09	663
	May	1,359	1.09	1,481
	June	1,628	1.08	1,758
-1941	July	998	1.07	1,068
	Aug.	1,332	1.01	1,345
	Sept.	1,528	.95	1,452
	Oct.	1,585	.95	1,506
	Nov.	1,731	.92	1,593
	Dec.	2,042	1.00	2,042
Total		14,749	1.02	15,052
	Jan.	1,957	.97	1,898
	Feb.	1,482	.97	1,438
	Mar.	1,494	.96	1,434
	Apr.	1,136	.98	1,113
	May	1,588	.98	1,556
	June	1,536	.98	1,505
-1942	July	1,226	.95	1,165
	Aug.	880	1.04	915
	Sept.	797	.97	773
	Oct.	845	.96	811
	Nov.	1,041	.96	999
	Dec.	1,213	.87	1,055
Total		15,195	.96	14,662
	Jan.	1,015	.91	924
	Feb.	746	.86	642
	Mar.	886	.95	842
	Apr.	877	.93	816
	May	957	.95	909
	June	976	.96	937
-1943	July	1,086	.89	967
	Aug.	990	.89	881
	Sept.	1,006	.88	885
	Oct.	1,160	.89	1,032
	Nov.	1,149	.85	977
	Dec.	1,231	.85	1,046
Total		12,079	.90	10,858
	Jan.	1,241	.88	1,092
	Feb.	1,223	.90	1,101
	Mar.	1,297	.93	1,206
	Apr.	1,164	.95	1,106
	May	1,116	.95	1,060
	June	983	.96	944
-1944	July	1,035	.93	963
	Aug.	1,168	.93	1,068
	Sept.	1,114	.87	969
	Oct.	1,178	.86	1,013
	Nov.	1,156	.86	994
	Dec.	1,187	[illegible]	1,080
Total		11,842	.91	12,596
	Jan.	1,186	.92	1,091
	Feb.	1,061	.89	944
	Mar.	1,232	.91	1,121
	Apr.	985	.92	906
	May	970	.92	892
	June	919	.97	891
-1945	July	913	.90	822
	Aug.	770	.88	678
	Sept.	824	.89	733
	Oct.	1,038	.83	862
	Nov.	1,036	.87	901
	Dec.	1,099	.88	967
Total		12,033	.90	10,808
	Jan.	1,041	.88	916
	Feb.	1,028	.94	966
	Mar.	944	.87	821
	Apr.	830	.90	747
	May	873	.92	803
	June	754	.90	679
-1946	July	801	.89	713
	Aug.	722	.87	628
	Sept.	730	.89	650
	Oct.	759	.89	676.
	Nov.	789	.89	702
	Dec.	870	.89	774
Total		10,141	.89	9,075
	Jan.	953	0.89	848
	Feb.	899	.90	809
	Mar.	940	.92	865
	Apr.	797	.95	757
	May	905	.96	869
	June	860	.96	826
-1947	July	844	.95	802
	Aug.	892	.94	838
	Sept.	819	.95	778
	Oct.	837	.89	745
	Nov.	880	85	748
	Dec.	1,037	.81	840
Total		10,663	.91	9,725
	Jan.	1,160	.93	1,079
	Feb.	1,160	.89	1,032
	Mar.	1,107	.89	985
	Apr.	1,083	.90	975
	May	1,115	.89	992
	June	989	.91	900
-1948	July	1,108	.88	975
	Aug.	986	.87	858
	Sept.	941	.86	809
	Oct.	918	.84	771
	Nov.	978	.79	773
	Dec.	1,106	.90	995
Total		12,651	.88	11,144
	Jan.	1,229	.87	1,069
	Feb.	1,192	.83	989
	Mar.	1,236	.82	1,014
	Apr.	1,116	.86	960
	May	983	.86	845
	June	923	.87	803
-1949	July	952	.87	828
	Aug.	1,013	.82	831
	Sept.	1,099	.81	890
	Oct.	1,148	.78	895
	Nov.	1,011	.75	758
	Dec.	1,158	.72	834
Total		13,060	.82	10,716
	Jan.	1,080	.84	907
	Feb.	1,036	.83	860
	Mar.	1,209	.82	991
	Apr.	998	.86	858
	May	1,066	.86	917
	June	900	.85	765
-1950	July	897	.83	745
	Aug.	833	.82	683
	Sept.	704	.82	577
	Oct.	651	.84	547
	Nov.	542	.86	466
	Dec.	557	.87	485
Total		10,473	.84	8,801
	Jan.	550	.87	479
	Feb.	501	.88	441
	Mar.	730	.88	642
	Apr.	765	.87	666
	May	675	.88	594
	June	862	.88	759
-1951	July	945	.89	841
	Aug.	945	.87	822
	Sept.	723	.86	622
	Oct.	709	.88	624
	Nov.	560	.88	493
	Dec.	707	.89	629
Total		8,672	.88	7,612
	Jan.	1,104	.89	983
	Feb.	1,134	.87	987
	Mar.	1,424	.87	1,239
	Apr.	1,300	.90	1,170
	May	1,443	.92	1,328
	June	1,419	.92	1,305
-1952	July	1,263	.88	1,111
	Aug.	1,296	.83	1,076
	Sept.	1,321	.79	1,044
	Oct.	1,234	.74	913
	Nov.	1,172	.69	809
	Dec.	1,303	.67	873
Total		15,413	.83	12,838
	Jan.	1,198	0.66	791
	Feb.	1,020	.81	826
	Mar.	947	.88	833
	Apr.	808	.91	735
	May	953	.90	858
	June	956	.90	860
-1953	July	1,093	.87	951
	Aug.	1,056	.84	887
	Sept.	823	.83	683
	Oct.	634	.84	533
	Nov.	527	.85	448
	Dec.	634	.85	539
Total		10,649	.84	8,944
	Jan.	797	.84	669
	Feb.	661	.83	549
	Mar.	782	.84	657
	Apr.	864	.84	726
	May	1,015	.89	903
	June	883	.92	812
-1954	July	1,000	.91	910
	Aug.	982	.91	894
	Sept.	754	.91	686
	Oct.	636	.92	585
	Nov.	638	.92	587
	Dec.	659	.92	606
Total		9,671	.89	8,584
	Jan.	734	.93	683
	Feb.	598	.94	562
	Mar.	733	.96	704
	Apr.	758	.97	735
	May	792	.99	784
	June	866	1.03	892
-1955	July	963	1.07	1,030
	Aug.	849	1.06	900
	Sept.	694	1.04	722
	Oct.	499	1.06	529
	Nov.	369	1.09	402
	Dec.	286	1.09	312
Total		8,141	1.01	8,255
	Jan.	317	1.10	349
	Feb.	365	1.10	402
	Mar.	628	1.10	691
	Apr.	684	1.09	746
	May	671	1.07	718
	June	787	1.09	858
-1956	July	865	1.10	952
	Aug.	823	1.09	897
	Sept.	634	1.12	710
	Oct.	486	1.08	525
	Nov.	321	1.11	356
	Dec.	288	1.14	328
Total		6,869	1.10	7,532
	Jan.	243	1.15	279
	Feb.	349	1.12	391
	Mar.	58[illegible]	1.09	642
	Apr.	731	1.06	775
	May	645	1.06	684
	June	783	1.05	822
-1957	July	890	1.03	917
	Aug.	817	1.01	825
	Sept.	661	.99	654
	Oct.	503	1.00	503
	Nov.	781	1.00	781
	Dec.	1,005	1.01	1,015
Total		7,997	1.04	8,288
	Jan.	1,285	.97	1,246
	Feb.	565	.93	525
	Mar.	1,345	.89	1,197
	Apr.	1,333	.87	1,160
	May	1,013	.85	861
	June	854	.84	717
-1958	July	930	.84	781
	Aug.	867	.82	711
	Sept.	714	.81	578
	Oct.	610	.82	500
	Nov.	623	.82	511
	Dec.	753	.83	625
Total		10,892	.86	9,412

To obtain mg/l multiply T/AF by 735.

Table 16

Colorado River Basin

Historical Flow and Quality of Water Data

Colorado River below Parker Dam, Arizona-California

Units-1000

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
	Jan.	677	0.82	555
	Feb.	593	.82	486
	Mar.	690	.82	566
	Apr.	832	.83	691
	May	706	.86	607
	June	797	.87	693
-1959	July	962	.84	808
	Aug.	873	.79	690
	Sept.	682	.80	546
	Oct.	558	.83	463
	Nov.	405	.84	340
	Dec.	411	.83	341
	Total	8,186	.83	6,786
	Jan.	428	.82	351
	Feb.	474	.81	384
	Mar.	760	.81	616
	Apr.	810	.85	689
	May	740	.86	636
	June	879	.88	774
-1960	July	986	.87	858
	Aug.	868	.88	764
	Sept.	640	.87	557
	Oct.	490	.86	421
	Nov.	397	.89	353
	Dec.	322	.91	293
	Total	7,794	.86	6,696
	Jan.	379	.91	345
	Feb.	453	.90	408
	Mar.	742	.90	668
	Apr.	725	.90	653
	May	705	.92	649
	June	822	.92	756
-1961	July	900	.91	819
	Aug.	710	.91	646
	Sept.	606	.90	545
	Oct.	412	.90	371
	Nov.	319	.94	300
	Dec.	202	.94	190
	Total	6,975	.91	6,350
	Jan.	334	.93	310
	Feb.	374	.92	344
	Mar.	692	.92	637
	Apr.	756	1/.94	711
	May	686	1/.95	652
	June	778	.97	755
-1962	July	882	.95	838
	Aug.	821	.97	796
	Sept.	644	.95	612
	Oct.	471	.96	452
	Nov.	434	.96	417
	Dec.	287	1.00	286
	Total	7,159	1/.95	6,810
	Jan.	350	.99	346
	Feb.	467	.98	458
	Mar.	735	.97	713
	Apr.	690	.97	670
	May	708	.95	672
	June	840	.93	781
-1963	July	933	.90	840
	Aug.	819	.89	729
	Sept.	630	.87	561
	Oct.	438	.87	381
	Nov.	334	.88	294
	Dec.	307	.89	273
	Total	7,251	.93	6,718
	Jan.	363	.90	327
	Feb.	479	.90	432
	Mar.	640	.89	570
	Apr.	652	.89	581
	May	598	.91	544
	June	742	.93	690
-1964	July	864	.94	812
	Aug.	795	.94	747
	Sept.	589	.92	542
	Oct.	409	.96	394
	Nov.	275	.96	264
	Dec.	245	1.00	244
	Total	6,651	.92	6,147

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
	Jan.	290	0.98	284
	Feb.	423	.99	419
	Mar.	634	1.00	634
	Apr.	581	1.01	587
	May	604	1.06	640
	June	710	1.05	746
-1965	July	846	1.06	897
	Aug.	867	1.06	919
	Sept.	599	1.05	629
	Oct.	385	1.08	416
	Nov.	220	1.08	237
	Dec.	197	1.05	207
	Total	6,356	1.04	6,615
	Jan.	177	0.82	145
	Feb.	413	1.04	430
	Mar.	604	1.08	652
	Apr.	729	1.06	773
	May	699	1.05	734
	June	790	1.03	814
-1966	July	901	1.03	928
	Aug.	852	1.02	869
	Sept.	585	1.00	585
	Oct.	357	1.00	357
	Nov.	256	1.00	256
	Dec.	320	1.00	320
	Total	6,683	1.03	6,863
	Jan.	306	1.00	306
	Feb.	431	1.00	431
	Mar.	677	1.03	697
	Apr.	608	.96	584
	May	648	.97	629
	June	726	.90	653
-1967	July	835	.87	726
	Aug.	749	.90	674
	Sept.	490	.90	441
	Oct.	435	.92	400
	Nov.	247	.93	230
	Dec.	170	.93	158
	Total	6,322	.94	5,929
	Jan.	351	.93	326
	Feb.	450	.92	414
	Mar.	680	.92	626
	Apr.	700	.94	658
	May	626	.92	576
	June	722	.96	693
-1968	July	779	.94	732
	Aug.	725	.95	688
	Sept.	585	.94	550
	Oct.	404	.98	396
	Nov.	309	.96	297
	Dec.	312	.95	296
	Total	6,643	.94	6,252
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			
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	May			
	June			
	July			
	Aug.			
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	Nov.			
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	Total			
	Jan.			
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	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
	Total			

To obtain mg/l multiply T/AF by 735.

Table 16
Colorado River Basin
Historical Flow and Quality of Water Data
Colorado River below Parker Dam, Arizona – California

(Annual Summary)

Units – 1000

Year	Flow (A.F.)	Concentration (T./A.F.)	Concentration (Mg./l)	T.D.S. (Tons)
1941	14,749	1.02	750	15,052
1942	15,159	.96	709	14,662
1943	12,079	.90	661	10,858
1944	13,842	.91	669	12,596
1945	12,033	.90	660	10,808
1946	10,141	.89	658	9,075
1947	10,663	.91	670	9,725
1948	12,651	.88	647	11,144
1949	13,060	.82	603	10,716
1950	10,473	.84	618	8,801
1951	8,672	.88	645	7,612
1952	15,413	.83	612	12,838
1953	10,649	.84	617	8,944
1954	9,671	.89	652	8,584
1955	8,141	1.01	745	8,255
1956	6,869	1.10	806	7,532
1957	7,997	1.04	762	8,288
1958	10,892	.86	635	9,412
1959	8,186	.83	609	6,786
1960	7,794	.86	631	6,696
1961	6,975	.91	669	6,350
1962	7,159	1/ .95	699	6,810
1963	7,251	.93	681	6,718
1964	6,651	.92	679	6,147
1965	6,356	1.04	765	6,615
1966	6,683	1.03	755	6,863
1967	6,322	.94	689	5,929
1968	6,643	.94	692	6,252
Total	273,210			250,068
Average	9,758	.92	673	8,931

1/ Partially estimated.

Records furnished by Metropolitan Water District of Southern California

Table 17

Colorado River Basin

Historical Flow and Quality of Water Data

Colorado River at Imperial Dam, Arizona - California

Units - 1000

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
-1941	Jan.	642	1.10	706
	Feb.	535	1.15	615
	Mar.	743	.90	669
	Apr.	562	1.04	584
	May	1,150	1.11	1,277
	June	1,605	1.21	1,942
	July	965	1.17	1,129
	Aug.	1,192	1.09	1,299
	Sept.	1,444	.99	1,430
	Oct.	1,505	1.02	1,535
	Nov.	1,671	1.02	1,704
	Dec.	2,010	1.04	2,090
	Total	14,024	1.07	14,980
-1942	Jan.	1,876	1.08	2,026
	Feb.	1,590	1.09	1,733
	Mar.	1,476	1.09	1,609
	Apr.	1,080	1.11	1,199
	May	1,524	1.10	1,676
	June	1,465	1.11	1,626
	July	1,199	1.11	1,331
	Aug.	844	1.09	920
	Sept.	742	1.11	824
	Oct.	761	1.08	822
	Nov.	981	1.03	1,010
	Dec.	1,176	.97	1,141
	Total	14,714	1.08	15,917
-1943	Jan.	1,011	.94	950
	Feb.	729	.92	671
	Mar.	846	.95	804
	Apr.	802	.96	770
	May	842	.98	825
	June	876	.98	858
	July	972	.95	923
	Aug.	910	.94	855
	Sept.	917	.94	862
	Oct.	1,094	.94	1,028
	Nov.	1,124	.93	1,045
	Dec.	1,222	.89	1,088
	Total	11,345	.94	10,679
-1944	Jan.	1,209	.89	1,076
	Feb.	1,216	.94	1,143
	Mar.	1,289	.97	1,250
	Apr.	1,126	1.00	1,126
	May	1,055	1.01	1,066
	June	900	1.02	918
	July	920	.99	911
	Aug.	1,041	.97	1,010
	Sept.	1,041	.94	979
	Oct.	1,123	.92	1,033
	Nov.	1,142	.89	1,016
	Dec.	1,143	.89	1,017
	Total	13,205	.95	12,545
-1945	Jan.	1,160	.98	1,137
	Feb.	1,047	.97	1,016
	Mar.	1,193	.97	1,157
	Apr.	947	.98	928
	May	905	1.00	905
	June	860	.99	851
	July	817	.96	784
	Aug.	718	.94	675
	Sept.	745	.92	685
	Oct.	912	.88	803
	Nov.	1,011	.89	900
	Dec.	1,075	.93	1,000
	Total	11,390	.95	10,841
-1946	Jan.	1,008	.94	948
	Feb.	1,005	.92	925
	Mar.	927	.94	871
	Apr.	759	.96	729
	May	786	.98	770
	June	658	.99	651
	July	719	.97	697
	Aug.	666	.94	626
	Sept.	639	.95	607
	Oct.	707	.97	686
	Nov.	757	.96	727
	Dec.	855	.94	804
	Total	9,486	.95	9,041
-1947	Jan.	933	0.95	886
	Feb.	872	.95	828
	Mar.	934	.98	915
	Apr.	737	1.02	752
	May	827	1.01	835
	June	787	1.02	803
	July	743	1.01	750
	Aug.	830	.99	822
	Sept.	733	1.00	733
	Oct.	753	.95	715
	Nov.	651	.90	586
	Dec.	1,041	.87	906
	Total	10,041	.97	9,711
-1948	Jan.	1,106	.97	1,073
	Feb.	1,135	.94	1,067
	Mar.	1,092	.95	1,037
	Apr.	1,007	.94	947
	May	1,051	.95	998
	June	916	.95	870
	July	1,003	.95	953
	Aug.	906	.94	852
	Sept.	871	.91	793
	Oct.	901	.89	802
	Nov.	945	.86	813
	Dec.	1,103	.94	1,037
	Total	12,036	.93	11,242
-1949	Jan.	1,237	.92	1,138
	Feb.	1,183	.88	1,041
	Mar.	1,226	.88	1,079
	Apr.	1,084	.91	986
	May	927	.92	853
	June	871	.93	810
	July	860	.92	791
	Aug.	934	.88	822
	Sept.	996	.86	857
	Oct.	1,103	.83	915
	Nov.	1,000	.93	930
	Dec.	1,146	.77	882
	Total	12,567	.88	11,104
-1950	Jan.	1,088	.89	968
	Feb.	994	.87	865
	Mar.	1,169	.88	1,029
	Apr.	936	.90	842
	May	1,002	.91	912
	June	841	.89	748
	July	822	.89	732
	Aug.	758	.88	667
	Sept.	643	.87	559
	Oct.	603	.94	567
	Nov.	510	.95	485
	Dec.	540	.95	513
	Total	9,906	.90	8,887
-1951	Jan.	558	.95	530
	Feb.	498	.96	478
	Mar.	635	.96	610
	Apr.	744	.96	714
	May	606	.99	600
	June	703	.98	689
	July	820	.98	804
	Aug.	853	.95	810
	Sept.	697	.93	648
	Oct.	682	.96	655
	Nov.	559	.97	542
	Dec.	698	.98	684
	Total	8,053	.96	7,764
-1952	Jan.	1,058	.95	1,005
	Feb.	1,107	.96	1,063
	Mar.	1,424	.92	1,310
	Apr.	1,279	.97	1,241
	May	1,345	1.00	1,345
	June	1,309	.99	1,296
	July	1,182	.97	1,147
	Aug.	1,178	.92	1,084
	Sept.	1,219	.87	1,061
	Oct.	1,240	.84	1,042
	Nov.	1,176	.78	917
	Dec.	1,298	.75	974
	Total	14,815	.91	13,485
-1953	Jan.	1,216	0.77	936
	Feb.	1,022	.89	910
	Mar.	911	.92	[illegible]
	Apr.	[illegible]	1.01	[illegible]
	May	[illegible]	1.01	[illegible]
	June	811	1.00	811
	July	950	[illegible]	[illegible]
	Aug.	911	.97	884
	Sept.	776	.93	722
	Oct.	644	.96	618
	Nov.	522	.97	[illegible]
	Dec.	720	.92	[illegible]
	Total	10,045	.94	9,411
-1954	Jan.	783	.94	736
	Feb.	661	.94	621
	Mar.	723	.94	680
	Apr.	773	.94	727
	May	929	1.05	975
	June	804	1.03	828
	July	885	1.01	894
	Aug.	887	1.03	914
	Sept.	719	1.02	733
	Oct.	620	1.03	639
	Nov.	602	1.02	614
	Dec.	644	1.03	663
	Total	9,030	1.00	9,024
-1955	Jan.	739	1.00	739
	Feb.	593	1.03	611
	Mar.	678	1.07	725
	Apr.	716	1.09	780
	May	729	1.13	824
	June	746	1.20	895
	July	882	1.21	1,067
	Aug.	811	1.18	957
	Sept.	638	1.17	746
	Oct.	499	1.20	599
	Nov.	379	1.24	470
	Dec.	298	1.29	384
	Total	7,708	1.14	8,797
-1956	Jan.	298	1.31	390
	Feb.	344	1.24	427
	Mar.	546	1.24	677
	Apr.	646	1.23	795
	May	594	1.26	748
	June	666	1.25	833
	July	753	1.25	941
	Aug.	717	1.22	875
	Sept.	583	1.24	723
	Oct.	479	1.24	594
	Nov.	343	1.28	439
	Dec.	297	1.30	386
	Total	6,266	1.25	7,828
-1957	Jan.	258	1.36	351
	Feb.	314	1.32	414
	Mar.	520	1.23	640
	Apr.	667	1.18	787
	May	581	1.19	691
	June	651	1.19	775
	July	794	1.22	969
	Aug.	759	1.08	820
	Sept.	616	1.12	690
	Oct.	511	1.16	593
	Nov.	695	1.14	792
	Dec.	978	1.10	1,076
	Total	7,344	1.17	8,598
-1958	Jan.	1,299	1.05	1,364
	Feb.	637	1.07	682
	Mar.	1,253	1.06	1,328
	Apr.	1,280	1.02	1,306
	May	1,016	1.00	1,016
	June	769	1.01	777
	July	812	.96	780
	Aug.	802	.97	778
	Sept.	655	.97	635
	Oct.	624	1.01	630
	Nov.	592	1.00	592
	Dec.	761	.97	738
	Total	10,500	1.01	10,626

To obtain mg/l multiply T/AF by 735.

Table 17

Colorado River Basin

Historical Flow and Quality of Water Data

Colorado River at Imperial Dam, Arizona - California

Units - 1000

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
	Jan.	674	0.99	667
	Feb.	598	.99	592
	Mar.	618	1.02	630
	Apr.	770	1.01	778
	May	646	1.05	678
	June	672	1.03	692
-1959	July	824	.99	816
	Aug.	821	1.04	854
	Sept.	644	1.04	670
	Oct.	565	1.01	582
	Nov.	421	1.04	438
	Dec.	441	1.01	445
Total		7,695	1.02	7,843
	Jan.	449	1.02	458
	Feb.	416	1.00	416
	Mar.	651	.99	644
	Apr.	742	.99	734
	May	650	1.07	695
	June	736	1.07	788
-1960	July	845	1.07	904
	Aug.	777	1.06	824
	Sept.	606	1.09	661
	Oct.	481	1.10	529
	Nov.	360	1.14	410
	Dec.	354	1.15	407
Total		7,107	1.06	7,511
	Jan.	342	1.18	404
	Feb.	400	1.15	460
	Mar.	648	1.10	713
	Apr.	666	1.08	719
	May	618	1.14	705
	June	691	1.08	746
-1961	July	755	1.09	823
	Aug.	671	1.12	752
	Sept.	541	1.14	617
	Oct.	427	1.10	470
	Nov.	312	1.12	349
	Dec.	322	1.16	373
Total		6,393	1.12	7,080
	Jan.	337	1.11	374
	Feb.	304	1.14	347
	Mar.	597	1.06	633
	Apr.	689	1.06	730
	May	619	1.11	688
	June	648	1.12	725
-1962	July	741	1.11	822
	Aug.	730	1.12	818
	Sept.	593	1.11	658
	Oct.	458	1.15	527
	Nov.	439	1.16	509
	Dec.	303	1.18	358
Total		6,458	1.11	7,189
	Jan.	337	1.14	384
	Feb.	393	1.11	436
	Mar.	615	1.10	676
	Apr.	647	1.09	705
	May	602	1.09	656
	June	691	1.06	733
-1963	July	775	1.04	806
	Aug.	757	1.02	772
	Sept.	595	1.04	619
	Oct.	461	1.08	498
	Nov.	340	1.12	381
	Dec.	309	1.13	350
Total		6,522	1.08	7,016
	Jan.	337	1.12	377
	Feb.	415	1.07	444
	Mar.	562	1.06	595
	Apr.	609	1.07	652
	May	530	1.10	583
	June	576	1.15	663
-1964	July	719	1.09	784
	Aug.	679	1.09	740
	Sept.	539	1.14	615
	Oct.	396	1.22	483
	Nov.	281	1.26	354
	Dec.	257	1.27	326
Total		5,900	1.12	6,616
	Jan.	271	1.26	341
	Feb.	332	1.26	418
	Mar.	548	1.20	658
	Apr.	566	1.15	651
	May	548	1.22	669
	June	558	1.22	680
-1965	July	709	1.26	893
	Aug.	737	1.28	943
	Sept.	540	1.31	708
	Oct.	400	1.29	516
	Nov.	257	1.33	342
	Dec.	237	1.22	290
Total		5,703	1.25	7,109
	Jan.	203	1.13	229
	Feb.	334	1.21	404
	Mar.	517	1.21	626
	Apr.	622	1.22	758
	May	576	1.24	715
	June	637	1.31	835
-1966	July	729	1.20	874
	Aug.	733	1.18	865
	Sept.	532	1.21	643
	Oct.	389	1.23	478
	Nov.	263	1.28	337
	Dec.	314	1.18	369
Total		5,849	1.22	7,133
	Jan.	301	1.21	364
	Feb.	369	1.16	428
	Mar.	593	1.12	664
	Apr.	558	1.15	642
	May	550	1.16	638
	June	595	1.16	690
-1967	July	673	1.08	727
	Aug.	672	1.09	732
	Sept.	450	1.16	522
	Oct.	412	1.12	461
	Nov.	268	1.22	327
	Dec.	174	1.35	235
Total		5,615	1.15	6,430
	Jan.	342	1.18	404
	Feb.	366	1.10	403
	Mar.	566	1.10	623
	Apr.	622	1.09	678
	May	532	1.18	628
	June	580	1.10	638
-1968	July	625	1.14	713
	Aug.	609	1.16	706
	Sept.	494	1.17	578
	Oct.	399	1.21	483
	Nov.	297	1.25	371
	Dec.	309	1.25	386
Total		5,741	1.15	6,611
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
Total				
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
Total				

Year	Month	Flow (A.F.)	Concentration (T./A.F.)	T.D.S. (Tons)
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
Total				
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
Total				
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
Total				
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
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	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
Total				
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
Total				
	Jan.			
	Feb.			
	Mar.			
	Apr.			
	May			
	June			
	July			
	Aug.			
	Sept.			
	Oct.			
	Nov.			
	Dec.			
Total				

To obtain mg/l multiply T/AF by 735.

Table 17
Colorado River Basin
Historical Flow and Quality of Water Data
Colorado River at Imperial Dam, Arizona — California

(Annual Summary)

Units - 1000

Year	Flow (A.F.)	Concentration (T./A.F.)	Concentration (Mg./1)	T.D.S. (Tons)
1941	14,024	1.07	785	14,980
1942	14,714	1.08	795	15,917
1943	11,345	.94	692	10,679
1944	13,205	.95	698	12,545
1945	11,390	.95	700	10,841
1946	9,486	.95	701	9,041
1947	10,041	.97	711	9,711
1948	12,036	.93	687	11,242
1949	12,567	.88	649	11,104
1950	9,906	.90	659	8,887
1951	8,053	.96	709	7,764
1952	14,815	.91	669	13,485
1953	10,045	.94	689	9,411
1954	9,030	1.00	735	9,024
1955	7,708	1.14	839	8,797
1956	6,266	1.25	918	7,828
1957	7,344	1.17	860	8,598
1958	10,500	1.01	744	10,626
1959	7,695	1.02	749	7,843
1960	7,107	1.06	777	7,511
1961	6,293	1.12	820	7,020
1962	6,458	1.11	818	7,189
1963	6,522	1.08	791	7,016
1964	5,900	1.12	824	6,616
1965	5,703	1.25	916	7,109
1966	5,849	1.22	896	7,133
1967	5,615	1.15	842	6,430
1968	5,741	1.15	846	6,611
Total	255,358			260,958
Average	9,120	1.02	751	9,320

Table 18

Summary of Historical and Present Modified Quality of Water and An

Colorado River Ba

Station 1	Historical condition Flow (AF) 2	T.D.S. (T) 3	Concentration (T/AF) 4	(mg/l) 5	Present modified condition Flow adjustment (AF) 6	Flow (AF) 7	T.D.S. adjustment (T) 8	T.D.S. (T) 9	Concentra (T/AF) 10
Green River near Green River, Wyoming	1,282	535	0.42	307	-24	1,258	+13	548	.44
Green River near Greendale, Utah	1,562	873	0.56	411	-7	1,555	+42	915	.59
Duchesne River near Randlett, Utah	448	411	0.92	674	-21	427	-1	410	.96
Green River at Green River, Utah	4,123	2,549	0.62	454	-60	4,063	+55	2,604	.64
San Rafael River near Green River, Utah	93	210	2.3	1,660	-15	78	+2	212	2.7
Colorado River near Glenwood Springs, Colorado	1,608	595	0.37	272	-203	1,405	-11	584	.42
Colorado River near Cameo, Colorado	2,758	1,523	0.55	406	-235	2,523	-5	1,518	.60
Gunnison River near Grand Junction, Colorado	1,697	1,451	0.86	628	-24	1,673	+20	1,471	.88
Colorado River near Cisco, Utah	4,925	4,158	0.84	621	-325	4,600	+44	4,202	.91
San Juan River near Archuleta, New Mexico	909	196	0.22	158	+6	916	+12	208	.23
San Juan River near Bluff, Utah	1,612	962	0.6	439	-24	1,588	+32	994	.63
Colorado River at Lees Ferry, Arizona	10,642	7,997	0.75	552	-434	10,208	+600	8,597	.84
Colorado River near Grand Canyon, Arizona	10,927	9,134	0.84	614	-434	10,493	+600	9,734	.93
Virgin River at Littlefield, Arizona	151	346	2.29	1,680	0	151	0	346	2.29
Colorado River below Hoover Dam, Ariz.-Nev.	10,682	9,991	0.94	687	-563	10,119	+467	10,458	1.03
Colorado River above Parker Dam, Ariz.-Calif.	10,277	9,419	0.92	673	-446	9,833	+529	9,948	1.01
Colorado River below Parker Dam, Ariz.-Calif.	9,758	8,931	0.92	673	-1,107	8,651	-179	8,752	1.01
Colorado River at Imperial Dam, Ariz.-Calif.	9,120	9,320	1.02	751	-1,273	7,847	-90	9,230	1.18

A

Table 18

of Water and Anticipated Effects of Future Developments at Eighteen Stations
Colorado River Basin

(Units: 1,000 except concentrations)

modified condition				Effects of future developments										
						Zero pickup				T.D.S. pickup at 2T/A				
D.S. djust-ment (T) 8	T.D.S. (T) 9	Concentration (T/AF) 10	Concentration (mg/1) 11	Flow adjust-ment (AF) 12	Flow (AF) 13	T.D.S. adjust-ment (T) 14	T.D.S. (T) 15	Concentration (T/AF) 16	Concentration (mg/1) 17	T.D.S. adjust-ment (T) 18	T.D.S. (T) 19	(T/AF) 20	(mg/1) 21
+13	548	.44	320	-231	1,027	-13	535	.52	383	+100	648	.63	464
+42	915	.59	432	-249	1,306	-13	902	.69	508	+100	1,015	.78	571
-1	410	.96	706	-206	221	-27	383	1.73	1,270	-11	399	1.81	1,330
+55	2,604	.64	471	-573	3,490	-50	2,554	.73	538	+116	2,720	.78	573
+2	212	2.7	2,000	-5	73	0	212	2.9	2,130	-8	204	2.8	2,050
-11	584	.42	306	-277	1,128	-24	560	.50	365	-24	560	.50	365
-5	1,518	.60	442	-475	2,048	-27	1,491	.73	535	+11	1,529	.75	549
20	1,471	.88	646	-69	1,604	0	1,471	.92	674	+65	1,536	.96	704
44	4,202	.91	671	-769	3,831	-51	4,151	1.08	796	+104	4,306	1.12	826
12	208	.23	167	-618	298	-137	71	.24	175	-137	71	.24	175
32	994	.63	460	-488	1,100	+7	1,001	.91	669	+384	1,378	1.25	921
00	8,597	.84	619	-1,892	8,316	-211	8,386	1.01	741	+478	9,075	1.09	802
00	9,734	.93	682	-1,892	8,601	-211	9,523	1.11	814	+478	10,212	1.19	873
0	346	2.29	1,680	-48	103	-2	344	3.34	2,450	+12	358	3.48	2,550
67	10,458	1.03	760	-2,180	7,939	-213	10,245	1.29	948	+490	10,948	1.38	1,010
29	9,948	1.01	744	-2,207	7,626	-236	9,712	1.27	936	+507	10,455	1.37	1,010
79	8,752	1.01	744	-2,008	6,643	-292	8,460	1.27	936	+355	9,107	1.37	1,010
00	9,230	1.18	865	-2,147	5,700	-292	8,938	1.57	1,150	+477	9,707	1.70	1,250

B

Table 19

Projects depleting Colorado River water

Project and state	New depletion (ac.-ft.)	New irrigation land (acres)
Above the gage Green River at Green River, Wyoming		
Seedskadee, Wyoming	145,000	58,000
Westvaco and others, Wyoming	86,000	[1]
Between the above gage and the gage Green River near Greendale, Utah		
Lyman, Wyoming	10,000	0
Utah Power & Light and others, Wyoming	8,000	[1]
Above the gage Duchesne River near Randlett, Utah		
Central Utah Project, Utah		
Bonneville Unit	166,000	[2]
Upalco Unit	10,000	0
Uintah Unit	30,000	7,800
Between the gages Green River near Greendale, Utah, and Duchesne River near Randlett, Utah, and the gage Green River at Green River, Utah		
Four County, Colorado	40,000	[2]
Hayden Steamplant, Colorado	12,000	[1]
Cheyenne-Laramie, Wyoming	24,000	[2]
Savery-Pot Hook, Colorado-Wyoming	27,000	17,920
Central Utah Project		
Jensen Unit	15,000	440
Above the gage San Rafael near Green River, Utah		
Utah Power & Light, Emery County, Utah	5,000	[1]
Above the gage Colorado River near Glenwood Springs, Colorado		
Denver-Englewood, Colorado	216,000	[2]
Green Mountain M&I, Colorado	12,000	[1]
Homestake Project, Colorado	49,000	[2]
Between the above gage and gage Colorado River near Cameo, Colorado		
Independence Pass Expansion, Colorado	14,000	[2]
Fryingpan-Arkansas, Colorado	70,000	[2]
Ruedi M&I, Colorado	38,000	[1]
West Divide, Colorado	76,000	19,000
Above the gage Gunnison River near Grand Junction, Colorado		
Fruitland Mesa, Colorado	28,000	15,870
Bostwick Park, Colorado	4,000	1,610
Dallas Creek, Colorado	37,000	15,000
Between the gages Colorado River near Cameo, Colorado, and Gunnison River near Grand Junction, Colorado, and the gage Colorado River near Cisco, Utah		
Dolores, Colorado	[3] 140,000	32,000
San Miguel, Colorado	85,000	26,000
Above the gage San Juan River near Archuleta, New Mexico		
San Juan-Chama, New Mexico	110,000	[2]
Navajo Indian Irrigation, New Mexico	[4] 508,000	110,000
Between the above gage and the gage San Juan River near Bluff, Utah		
Animas-La Plata, Colorado-New Mexico	146,000	46,500
Expansion Hogback, New Mexico	10,000	0
Utah Construction Co., New Mexico	25,000	[1]
Return flow--Dolores and Navajo Indian Irrigation, Colorado and New Mexico	-311,000	[3] [4]
Between the gages Green River at Green River, Utah; San Rafael River near Green River, Utah; Colorado River near Cisco, Utah; and San Juan River near Bluff, Utah; and the gage Colorado River at Lees Ferry, Arizona		
Resources, Inc., Utah	102,000	[1]
Arizona M&I, Arizona	35,000	[1]
Salvage	-80,000	
Subtotal Upper Basin	1,892,000	350,140
Between the above gage and the gage Colorado River near Grand Canyon, Arizona	0	0
Above the gage Virgin River at Littlefield, Arizona		
Dixie Project, Utah	[5] 48,000	6,900
Between the gages Colorado River near Grand Canyon, Arizona, and Virgin River at Littlefield, Arizona, and the gage Colorado River below Hoover Dam, Arizona-Nevada		
Southern Nevada Water Project, Nevada	[6] 240,000	[1]
Between the above gage and the gage Colorado River below Parker Dam, Arizona-California		
Fort Mohave and Chemehuevi Indian, Arizona, California, and Nevada	83,000	20,900
Central Arizona, Arizona[7]	433,000	
Reduced Metropolitan Water District Diversions[7]	-433,000	
Kingman, Arizona	18,000	[1]
Mohave Valley I&D District, Arizona	6,000	[1]
Lake Havasu I&D District, Arizona	7,000	[1]
Salvage	-87,000	
Reduced Metropolitan Water District Diversions[7]	-199,000	
Between the above gage and the gage Colorado River at Imperial Dam, Arizona-Colorado		
Colorado River Indian, Arizona-California	243,000	60,840
Salvage	-104,000	
Subtotal Lower Basin	255,000	88,640
Total Colorado River	2,147,000	438,780

[1] In-basin depletion without irrigated lands.

[2] Transmountain diversion.

[3] In-basin transfer from Dolores River drainage to the San Juan River drainage--estimated 53,000-acre-foot return flow to the San Juan River.

[4] Diversions at Navajo Reservoir, estimated 258,000-acre-foot return flow to the San Juan River below the gage near Archuleta, New Mexico.

[5] Includes a transmountain diversion to Great Basin.

[6] Pending full development, the Mohave Thermal Plant will use part of this water which will be diverted below Hoover Dam.

[7] The Central Arizona Project diversions will vary, depending on the depletions by other projects on the river. Under present modified conditions maximum diversions to Central Arizona could be 2,172,000 acre-feet but with full depletions by the projects tabulated, the maximum diversions would be 433,000 acre-feet. Also with full depletions by the projects tabulated, the diversions to the Metropolitan Water District of Southern California would be reduced to an annual 550,000 acre-feet from its present diversions of 1,182,000 acre-feet. This will provide 199,000 acre-feet needed to develop the other tabulated projects in the Lower Basin in addition to the 433,000 acre-feet delivered to the Central Arizona Project.

Table 20

Units: 1,000[1/] Dissolved constituent loads of Green River at Green River Utah

		Ionic loads in tons equivalent								T.D.S.	
Calendar year	Mean discharge (a.f.)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	SAR[2/]	Kx10^6 at 25° C. [3/]	Tons	mg/l
1941	4,608	21	14	20	21	28	6	1.9	*775	3,271	522
1942	4,622	20	13	17	20	25	5	1.7	*715	2,989	475
1943	4,294	17	11	15	18	21	4	1.6	*670	2,565	439
1944	4,417	18	11	16	20	21	4	1.6	682	2,582	430
1945	4,260	18	11	14	20	20	4	1.5	679	2,558	441
1946	3,519	15	9	12	17	16	4	1.6	689	2,148	449
1947	5,523	21	13	17	24	23	5	1.4	615	2,991	398
1948	3,928	16	10	13	17	18	4	1.5	647	2,270	425
1949	5,129	22	13	17	24	23	5	1.5	671	3,039	435
1950	5,476	24	14	17	27	24	5	1.4	669	3,223	433
1951	4,738	20	12	15	22	22	4	1.3	656	2,847	442
1952	6,712	30	18	22	33	31	6	1.4	692	4,172	457
1953	3,334	15	10	13	16	18	4	1.6	730	2,225	491
1954	2,638	12	7	11	12	15	3	1.7	755	1,807	503
1955	2,791	12	7	11	12	14	3	1.6	695	1,733	456
1956	4,021	15	9	11	16	15	4	1.3	575	2,045	374
1957	5,808	22	13	17	25	24	5	1.3	587	3,060	387
1958	4,212	16	11	14	18	19	4	1.5	640	2,421	422
1959	2,884	12	7	11	12	15	3	1.7	696	1,802	459
1960	2,864	11	6	10	12	13	3	1.5	604	1,645	422
1961	2,265	10	6	9	10	12	3	1.6	707	1,450	471
1962	5,601	21	12	17	22	23	4	1.4	621	3,077	404
1963	1,576	7	5	8	7	11	2	2.2	854	1,241	579
1964	3,242	14	8	11	14	15	3	1.6	686	2,044	463
1965	5,211	22	14	19	22	28	5	1.7	721	3,412	481
1966	2,966	13	10	13	13	20	3	1.9	820	2,260	560
1967	4,227	21	13	18	18	30	4	1.8	811	3,257	566
1968	4,589	20	13	18	19	28	4	1.7	741	3,225	517
Total	115,455	485	300	406	509	572	113	-	-	71,359	-
Mean	4,123	17	11	14	18	20	4	1.6	684	2,549	454

Table 21

Units: 1,000[1/] Dissolved constituent loads of Colorado River near Cisco, Utah

		Ionic loads in tons equivalent								T.D.S.	
Calendar year	Mean discharge (a.f.)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Choloride (Cl)	SAR[2/]	Kx10^6 at 25° C. [3/]	Tons	mg/l
1941	7,067	35	22	34	24	51	15	1.8	*900	5,653	588
1942	7,098	34	22	33	24	49	15	1.8	*870	5,483	568
1943	5,214	28	18	27	19	41	13	1.9	*960	4,498	634
1944	5,840	30	16	26	22	37	14	1.7	848	4,336	546
1945	5,504	28	16	25	21	36	14	1.8	867	4,210	562
1946	4,058	24	15	22	16	34	11	2.0	1,010	3,680	667
1947	6,258	32	17	27	22	39	14	1.7	821	4,587	539
1948	6,291	33	18	27	24	38	15	1.6	826	4,636	542
1949	6,338	32	18	29	24	39	16	1.8	859	4,783	555
1950	4,074	24	15	24	16	33	14	2.1	1,040	3,823	690
1951	3,986	23	14	23	14	32	13	2.1	1,010	3,758	693
1952	7,718	34	19	27	26	39	15	1.4	724	5,063	482
1953	4,062	24	15	25	15	34	15	2.2	1,060	3,944	714
1954	2,293	19	13	22	10	30	13	3.1	1,570	3,299	1,060
1955	3,185	21	13	22	12	30	14	2.4	1,180	3,420	789
1956	3,568	22	13	21	13	30	13	2.1	1,060	3,428	706
1957	8,888	42	18	31	29	44	19	1.4	721	5,602	463
1958	6,044	29	15	26	19	36	16	1.6	814	4,348	529
1959	3,214	22	13	22	12	31	13	2.4	1,200	3,481	796
1960	4,002	23	13	21	14	31	13	1.9	964	3,493	642
1961	3,395	24	12	22	12	32	13	2.2	1,150	3,556	770
1962	6,576	33	14	26	22	35	15	1.6	764	4,484	501
1963	2,585	21	11	21	10	30	13	2.8	1,390	3,384	962
1964	3,433	22	13	21	13	28	14	2.2	1,110	3,639	779
1965	6,722	32	17	28	22	37	17	1.7	807	4,892	535
1966	3,163	20	13	22	12	30	13	2.4	1,170	3,471	807
1967	3,146	22	12	24	13	31	14	2.7	1,210	3,602	842
1968	4,185	23	15	23	15	32	14	2.1	991	3,869	680
Total	137,907	756	430	701	495	989	398	-	-	116,422	-
Mean	4,925	27	15	25	18	35	14	1.9	934	4,158	620

1/ Except SAR, specific conductance, and mg/l. *Correlated

2/ Sodium adsorption ratio

3/ Specific conductance.

Mg/l of ion = 735 x Ionic load x atomic st. of ion ÷ discharge (af).

Table 22

Units: 1,000 1/ Dissolved constituent loads of San Juan River near Bluff, Utah

Calendar year	Mean discharge (a.f.)	Ionic loads in tons equivalent						SAR 2/	Kx10^6 at 25° C. 3/	T.D.S.	
		Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)			Tons	mg/1
1941	4,899	23	8	12	18	23	2	1.1	608	2,625	394
1942	2,247	10	5	5	8	11	1	1.0	582	1,185	388
1943	1,494	8	4	5	6	[illegible]	1	1.3	699	959	472
1944	2,291	10	4	5	8	10	1	.9	537	1,101	353
1945	1,588	8	4	5	6	9	1	1.2	647	935	433
1946	887	6	3	4	4	7	1	1.5	818	681	564
1947	1,677	9	4	6	6	11	1	1.5	694	1,087	476
1948	2,140	9	3	5	7	9	1	1.0	498	976	335
1949	2,487	11	4	5	8	11	1	1.0	516	1,168	345
1950	854	5	3	3	3	6	1	1.3	724	579	498
1951	691	4	2	3	3	6	1	1.6	812	544	579
1952	2,554	10	4	5	8	10	1	.9	488	1,156	333
1953	967	6	3	4	4	7	1	1.5	754	701	533
1954	1,011	6	3	4	4	8	1	1.6	803	779	566
1955	910	5	2	4	4	7	1	1.6	769	667	539
1956	838	4	2	3	3	5	1	1.3	673	535	469
1957	2,909	13	5	7	9	13	2	1.2	555	1,498	378
1958	2,298	9	4	5	7	10	1	1.0	527	1,116	357
1959	712	5	2	4	3	6	1	1.8	853	578	597
1960	1,607	7	3	5	5	8	1	1.2	563	847	387
1961	1,264	7	3	5	5	8	1	1.4	702	336	486
1962	1,480	7	2	5	4	8	1	1.4	637	877	436
1963	579	4	2	3	2	7	1	2.1	1,110	635	806
1964	795	5	2	4	3	8	1	2.1	979	781	722
1965	2,546	10	5	6	8	13	1	1.2	589	1,379	398
1966	1,548	7	4	5	5	10	1	1.4	683	996	473
1967	791	5	3	5	4	8	1	2.3	1,040	831	772
1968	1,060	6	3	5	4	9	1	1.6	835	874	606
Total	45,124	219	96	137	159	257	30	-	-	26,957	-
Mean	1,612	8	3	5	6	9	1	1.3	641	963	439

Table 23

Units: 1,000 1/ Dissolved constituent loads of Colorado River at Lees Ferry, Arizona

Calendar year	Mean discharge (a.f.)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Bicarbonate (HCO3)	Sulfate (SO4)	Chloride (Cl)	SAR 2/	Kx10^6 at 25° C. 3/	T.D.S.	
										Tons	mg/1
1941	17,857	91	48	60	68	115	24		*770	12,481	514
1942	14,793	62	39	46	51	84	19		*700	9,381	466
1943	11,413	52	33	49	39	74	21	1.8	808	8,375	539
1944	13,019	54	33	50	42	74	22	1.7	732	8,525	481
1945	11,769	57	33	48	44	71	22		*800	8,501	531
1946	8,751	52	29	39	39	64	20		*910	7,346	617
1947	14,046	72	38	48	55	82	20		*760	9,513	498
1948	12,885	61	32	48	48	71	21	1.5	748	8,531	487
1949	14,604	71	38	54	58	82	24	1.5	769	9,954	501
1950	10,802	55	33	45	44	70	20	1.7	844	8,098	551
1951	9,901	54	30	43	41	67	20	1.7	882	7,833	581
1952	17,903	82	43	61	70	92	24	1.4	710	11,396	468
1953	8,729	49	29	44	36	66	20	1.9	943	7,485	630
1954	6,165	42	22	39	29	57	18	2.3	1,130	6,386	761
1955	6,966	45	24	38	33	56	18	2.0	1,020	6,548	691
1956	8,658	48	24	36	37	52	18	1.6	840	6,513	553
1957	18,700	101	41	58	82	92	25	1.3	766	12,646	497
1958	13,139	71	30	47	58	70	22	1.4	782	9,280	519
1959	7,061	44	22	39	30	55	18	2.0	1,010	6,766	704
1960	8,790	51	20	38	36	54	17	1.7	851	7,092	593
1961	7,314	51	21	38	31	59	18	1.9	1,030	7,065	710
1962	14,439	76	31	52	61	76	22	1.5	763	10,319	525
1963	1,384	10	6	11	6	15	6	3.0	1,350	1,758	934
1964	3,243	23	11	21	13	31	11	2.4	1,200	3,578	811
1965	11,585	61	29	51	41	78	23	1.9	865	9,008	572
1966	7,739	37	20	32	26	49	13	1.9	802	5,439	517
1967	7,560	41	22	39	27	57	18			6,387	621
1968	8,782	49	28	47	33	70	21			7,725	647
Total	297,990	1,562	809	1,221	1,178	1,883	545	-	-	223,929	-
Mean	10,642	56	29	44	42	67	19	1.7	831	7,997	552

*Correlated

1/ Except SAR, specific conductance, and mg/1.
2/ Sodium adsorption ratio.
3/ Specific conductance.
Mg/1 of ion = 735 x Ionic load x atomic of ion ÷ discharge (a.f.).

Table 24

Units: 1,000 1/ Dissolved constituent loads of the Colorado River below Hoover, Dam, Ariz.-Nev.

Calendar year	Mean discharge (a.f.)	Ionic loads in tons equivalent Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Bicarbonate (HCO3)	Sulfate (SO4)	Chloride (Cl)	SAR 2/	Kx10⁶ at 25° C. 3/	T.D.S. Tons	T.D.S. mg/l
1941	14,889	107	44	83	50	143	43	2.1	1,110	14,897	735
1942	15,762	109	48	88	56	146	43	2.1	1,070	15,381	717
1943	12,715	80	37	67	44	108	31	2.1	1,010	11,502	665
1944	14,427	90*	44*	77*	52*	122*	39*	2.1	1,040	13,607	693
1945	12,512	76*	36*	64*	45*	98*	34*	2.1	1,020	11,512	676
1946	10,585	63*	32*	54*	38*	83*	29*	2.1	1,010	9,626	668
1947	10,959	66*	33*	59*	40*	87*	31*	2.2	1,020	10,283	690
1948	13,051	80*	38*	67*	47*	104*	34*	2.1	989	11,713	660
1949	13,566	79*	39*	69*	48*	104*	35*	2.1	947	11,250	610
1950	12,016	70*	35*	59*	43*	89*	32*	2.0	963	10,046	614
1951	9,870	56	31*	53*	37*	76*	28*	2.2	978	9,005	671
1952	15,816	86	45	79	55*	116*	40*	2.1	938	13,401	623
1953	11,302	66	31	5[illegible]	41*	85*	29*	2.1	974	10,093	656
1954	10,514	65	30	58	39*	85*	29*	2.2	1,030	9,913	693
1955	8,589	61	27	56	33*	81*	31*	2.5	1,190	9,393	804
1956	7,812	54	29	54	30	76*	31*	2.6	1,230	8,918	839
1957	9,323	61*	30*	58*	35*	82*	33*	2.4	1,140	9,681	763
1958	11,877	68	31	58	41	87*	30*	2.0	948	10,243	634
1959	9,282	52	25	44	33	67*	23*	2.0	944	7,841	621
1960	8,997	55	25	48	32	70*	26*	2.2	1,000	8,209	671
1961	8,586	54*	27*	48*	31*	71*	28*	2.2	1,040	8,139	697
1962	8,615	55*	25*	48*	31*	71*	26*	2.2	1,100	8,033	685
1963	8,533	52*	24*	45*	31*	66*	25*	2.1	1,020	7,882	677
1964	8,163	51*	25*	48	28	69	29	2.4	1,070	8,014	722
1965	7,792	54	26	54	28	71	32	2.6	1,220	8,574	809
1966	7,777	49	26	52	27	69	30	2.7	1,150	7,857	743
1967	7,932	47	24	47	27	64	27	2.4	1,060	7,282	675
1968	7,839	47	26	49	28	65	28	2.5	1,100	7,457	699
Total	299,101	1,853*	893*	1,644*	1,070*	2,455*	873*	-	-	279,752	-
Mean	10,682	66*	32*	59*	38*	88*	31*	2.2	1,040	9,991	687

Table 25

Units: 1,000 1/ Dissolved consitutent loads of Colorado River at Imperial Dam, Ariz.-Calif.

Calendar year	Mean discharge (a.f.)	Ionic loads in tons equivalent Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Bicarbonate (HCO3)	Sulfate (SO4)	Chloride (Cl)	SAR 2/	Kx10⁶ at 25° C. 3/	T.D.S. Tons	T.D.S. mg/l
1941	14,024	95	42	89	48	130	49	2.4	1,140	14,980	785
1942	14,714	102	45	91	51	139	46	2.4	1,140	15,917	795
1943	11,345	73	34	64	40	98	31	2.2	1,040	10,679	692
1944	13,205	82	42	77	49	114	39	2.3	1,070	12,545	698
1945	11,390	69	38	66	41	98	36	2.3	1,070	10,841	700
1946	9,486	56	31	56	34	80	31	2.4	1,060	9,041	701
1947	10,041	62	34	60	37	86	34	2.4	1,080	9,711	711
1948	12,036	73	38	69	45	100	36	2.1	1,060	11,242	687
1949	12,567	73	38	64	46	96	35	2.1	986	11,104	649
1950	9,906	57	30	54	37	76	30	2.2	1,010	8,887	659
1951	8,053	47	26	49	31	65	27	2.5	1,060	7,764	709
1952	14,815	82	46	83	54	113	44	2.3	1,010	13,485	669
1953	10,045	57	32	57	38	79	31	2.3	1,030	9,411	689
1954	9,030	53	29	56	35	74	31	2.5	1,070	9,024	735
1955	7,709	51	29	56	29	75	32	2.7	1,230	8,797	839
1956	6,266	45	24	51	24	67	31	3.0	1,350	7,828	918
1957	7,344	53	27	56	28	73	34	2.8	1,310	8,598	860
1958	10,500	65	30	69	39	87*	37*	2.6	1,100	10,626	744
1959	7,695	47	22	49	28	63*	28*	2.6	1,100	7,843	749
1960	7,107	46	20	48	26	60*	29*	2.7	1,160	7,511	777
1961	6,293	42	19	47	23	57*	29*	2.9	1,220	7,020	820
1962	6,458	43	21	51	24	61	31	3.0	1,270	7,189	818
1963	6,522	44	19	49	24	59	29	2.9	1,220	7,016	791
1964	5,900	38	19	47	22	55	28	3.1	1,270	6,616	824
1965	5,703	40	20	50	21	59	31	3.2	1,390	7,109	916
1966	5,849	40	21	53	22	60	32	3.4	1,380	7,133	896
1967	5,615	36	19	48	22	53	28	3.3	1,310	6,430	842
1968	5,741	36	20	49	23	54	29	3.3	1,310	6,611	846
Total	255,538	1,607	815	1,658	941	2,231*	928*	-	-	260,958	-
Mean	9,120	57	29	59	34	80*	33*	2.5	1,120	9,320	751

1/ Except SAR, specific conductance, and mg/l.

*Estimated or partially estimated.

2/ Sodium adsorption ratio.

3/ Specific condustance.

Mg/l of ion = 735 x Ionic load x atomic wt. of ion ÷ discharge (a.f.).

Table 26
Temperature of Water
Green River near Green River, Wyoming
(Units: °F)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total	Mean
1941														
1942														
1943														
1944														
1945														
1946														
1947														
1948														
1949														
1950														
1951					54*	56	65*	63	56*	44*	34	33		
1952	33*	32	33	41	56*	64*	66*	66	61*	48*	35	33*	568	47
1953	34	34*	37*	47*	53	63*	71	70	63*	50	40*	33	595	50
1954	34	34*	35*	47*	54*	58	68	64*	58	46	40	33*	571	48
1955	34	34	34	41	57*	63*	67	68*	56	48	35*	34*	571	48
1956	34*	34*	37*	44	55*	62	66	63*	57	44	34*			
1957				46	54	61	68	69	56*					
1958					57	64	66	68	59	47				
1959					52	63	67	65	58	45*				
1960				50	60*		72	69*						
1961				48*		68*	73*	72*	59*	45*				
1962					53	61	67	65	57	49		32		
1963	32	33	36*	46*	58	63	68*	69	63*	53*		32		
1964	32	32		40	55	59	69	66	58	49	36*	33		
1965	32	33	33	46	53	58	65	67	55*	49	38*	32	561	47
1966	33		35*	44	57*	63	71	67	61*	45	37	33		
1967	33	33	35	44	53	58	68	68	58	46	36	32	564	47
1968	32*	34	36	43	54	59	68	61	57	50*	36	32	562	47
Total	363	333	351	627	935	1,043	1,225	1,200	992	758	401	392		
Mean	33	33	35	45	55	61	68	67	58	47	36	33	571	48

*Incomplete Record

Table 27
Temperature of Water
Green River near Greendale, Utah
(Unit: °F.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total	Mean
1941														
1942														
1943														
1944														
1945														
1946														
1947														
1948														
1949														
1950														
1951														
1952														
1953														
1954														
1955														
1956														
1957														
1958														
1959	33	33	34	46	54	64	68	67		48	36	32		
1960														
1961														
1962														
1963										43*	53*	47		
1964	41	37	38*	41*	41	42	45	47	48*	54*	53*	46*	533	44
1965	41*	38	39*	40	42*	46	49*	50*	51	53*	53*	49	551	46
1966	44	41*	39	39	39	39	41*	42*	44	45	46*	46	505	42
1967	41	39	38*	39	40	41	43	45	46*	46*	48	46	512	43
1968	41	39	39	39	39	39	41*	45*	46	50	52	46*	516	43
Total	241	227	227	244	255	271	287	296	235	339	341	312		
Mean	40	38	38	41	42	45	48	49	47	48	49	45		44

*Incomplete Records.

Table 28
Temperature of Water
Green River at Green River, Utah
(Unit: °F.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total	Mean
1941														
1942														
1943														
1944														
1945														
1946														
1947														
1948														
1949					60*	65*	75*	76*	69*	54*	44*	35*		
1950	33*	37*	40*	53*	58*	66	73*	74*	67*		42*	35*		
1951	34*		44*	54*	61*	67*	77*	75*	68*		40*	33*		
1952	33*	35*	39*	48*						59*	43*	33*		
1953	34*	36*		52*	59*	67*	77*	73*	68*			33*		
1954	34	39*	44*	58*	65*	68*	77	74*	70*	57*	46*	34*	666	56
1955	32*	32*	36*	50*	59*	67*	75*	77	69	57*	40*	35*		
1956	35*	35*	44*	53*	62*	68*	75*	73*	64*	58*	39	33*	639	53
1957	32*	37*	43*	52*	59	65*	73*	75*				36*		
1958			47*	55*	64*	72	79*	80*	71*					
1959			48	58*	64*	72	76*							
1960														
1961														
1962														
1963														
1964														
1965				48*			74*							
1966							78*	75*	67*	53*	42*	33*		
1967	32	33*	38*	50*	57*	62*	72	73*	63*	54*	39	32	605	50
1968	32	32	37	50*	59*	64	72*	64*	59	52	43	32	596	50
Total	331	316	460	681	727	803	1,053	889	735	444	418	404	638	
Mean	33	35	42	65	61	67	75	74	67	56	42	34		53

*Incomplete Records.

Table 29
Temperature of Water
Colorado River near Glenwood Springs, Colorado
(Unit: °F.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total	Mean
1949					51	54	62	65	60	49	41	36		
1950	35	35	39	46	50*	54	63	63*	59	51	41	35	571	48
1951	33*	33	39*	47	51	53	62	62*	57*	47	34	32	550	46
1952	33	33*	34	45	50	55	62*	62*	58	48*	36	32*	548	46
1953	32	33	39*	45	49	55	64*	62*	57	48	38	32	554	46
1954	32	35*	38*	50	54*	59*	68*	65	60	49	39	32	581	48
1955	32*	32	36	45*	52	56*	66*	66*	59	50	36*	33*	563	47
1956	33*	32	37	47*	52	59*	65	62	57	47	34	32*	557	46
1957	32	33	38	45	48	52*	58	61	54*	47	35	32*	535	45
1958	32	34	37	43	49	55	61	65*	56	46	37	33*	548	46
1959	32	32*	39*	47	52	56	64	64*	56*	45	35	32	554	46
1960	32	32*	38	46	50	56	63	63*	59*	49*	37*	32*	557	46
1961		33*	39*	47	53	58*	65*	66	53*	46	36			
1962			36	44	48	53	60*	61	57*	49	40*	32*		
1963	32	33	37	45*	53*	58	67*	65*	60*	55*	44	34	583	49
1964	34	36	41	50	52	55	65	65	61	47*	36*	32	574	48
1965	32	32	36*	45*	49*	52*	58*	60*	52*	47*	40*	32*	535	45
1966	32*	33*	39*	47*	51	57*	66*	65	59*	46*	38*	34*	567	47
1967	33*	34*	37*	46	50	54	64*	62*	57*	47	36	32	552	46
1968	32	33*	38*	44	51*	54	62*	61	55*	46*	35*	32*	543	45
Total	553	598	717	874	1,015	1,105	1,265	1,265	1,146	959	748	621		
Mean	33	33	38	46	51	55	63	63	57	48	37	33	557	46

*Incomplete Record

Table 30
Temperature of Water
Colorado River Below Colorado-Utah State Line
(Units: °F)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total	Mean
1962						63	69	73*	67	57	45	37		
1963	34	37	44	51	60	68	73	74	67	59	46	35	648	54
1964	34	34	41	52	57	62	76	72	65	54	40	34	621	52
1965	35	37	43	51	56*	59	68	70	61	55	45	35	615	51
1966	32	34	45	54	62	67	75*	73		54	43			
1967	33	37*	47	52	58	62	72	73	62	52	41	34	623	52
1968	32	36		52				64*	63*	57*				
Total	200	215	220	312	293	381	433	499	385	388	260	175		
Mean	33	36	44	52	59	64	72	71	64	55	43	35	628	52

*Incomplete Record.

Table 31
Temperature of Water
San Juan River near Archuleta, New Mexico
(Units: °F)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total	Mean
1941														
1942														
1943														
1944														
1945														
1946														
1947														
1948														
1949				48	55	58	69	69	62	52	39	34		
1950	33	40	46	54	58	67	74	72*	64*	59	44	37*	648	54
1951	33	38*	47	53	58*	65	76*	75	67	54*	42*	33	641	53
1952	33*	36*	41	51*	55	61	70	75*	66*		40			
1953		38	48*	57	59*	67		76*	69*		43*			
1954	34*	39*	47*	60*	64*	69*	80*	73*	72*					
1955	32	33	41	48	54	60	67	72	63*	55	39*	33*	597	50
1956	37	38	44	50	56*	65	72	69*	62	52	35	32*	612	51
1957	32	36	42	45	51	54	61	66*	59	52	39*	34	571	48
1958	33	33	39	44	51	59	66	69	61	53*		36*		
1959		37	43	50	54	57*	67	67	60	50*	38			
1960	32*	32	37	46	52	57	70	73	68	54	42	36	599	50
1961	33	37*	45*	51	57	68	74*	74	64	53	41	34	631	52
1962	32	34	43	51	55	64	75	75	68	61	50	42	650	54
1963	35	42	43*		60	64*	64	64	62		52*	45*		
1964	39*	39	41	45	53	54	62	59	60	59	48	43		
1965			42*	45*	49*	53	61*	55*			52	47		
1966	41	40	40	44	48	55	62*	57	58	51	50	43	589	49
1967	37	39	41	46	51	55	58*	52	50	52	50	43*	574	48
1968	39	41	39	43	48	59	61	55	55	52	46	43	581	48
Total	555	672	809	931	1,088	1,211	1,289	1,347	1,190	809	790	615		
Mean	35	37	43	49	54	61	68	67	63	54	44	38	613	51

*Incomplete Record

Table 32
Temperature of Water
San Juan River near Bluff, Utah
(Unit: °F.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total	Mean
1941														
1942														
1943														
1944										56	44	34*		
1945	35*	40	44*	50*	59*	68*	75*	75*	67*	54*	42*	33*	642	54
1946	34*	39	47*	59*		70	78*	76	67*	54*	42*	37*		
1947	32*	40	48	54	64	66	75*	73	68*	58	40*	35*	653	54
1948	34*	39*	43*	52*	61	67*	75*	73	67*	55*	40*			
1949	34*	36*	48*	56*	60*	65	74	73	69*	54	44	35*	648	54
1950	34*	42	51	67	68	74*	76	74*	68	61	45	41*	701	58
1951	38*	43*			62*									
1952	35*	39*	42	54	61*	65*	74*	75	67*	60*	43	35*	650	54
1953	36	39	47*	52	59*	68*	75	71	63*	54*	43*			
1954	36*	42*	44	58*	64	68	76*	72	68*	56*	44*			
1955	34*		44	50*	59	65	72	74	66	56*	41*	40*		
1956	39*	38*	45	54*	61	69*	74*	69	65	53*		34*		
1957		43	47		57*	64	76*	72	68*	56*	41*	35		
1958	35*	41*	44*	51	61	68	76	75	66	57	43*	40*	657	55
1959	36*	40*	47*	56*	60*	71*	74*	72*	63*	55*	42*			
1960	33*	37	47*	53*	61*	68*	75*	72*	69*	54*	43	34*	646	54
1961	33*	39*	47	53*	60	70	76	72*	63*					
1962														
1963														
1964														
1965	39	41	47*	58*	62*	66	75	75	66	58	50	41	678	56
1966	36	39	48	57	66*	73*	81	78*	71	56	47	37	689	57
1967	33*	40	50	56	55	70	77	75	70	57	41	32	656	55
1968	32	41	48	54*	63	70	79	72	68	57*	43	36	663	55
Total	698	798	928	1,044	1,223	1,365	1,513	1,468	1,339	1,121	818	579		
Mean	35	40	46	55	61	68	76	73	67	56	43	36		55

*Incomplete Record

Table 33
Temperature of Water
Colorado River at Lees Ferry, Arizona
(Unit: °F.)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	Mean
1949								76	72	58	47	37	290	
1950	36	42	49	58	62	68	77	77	70	62	48	40	689	57
1951	36	40	48	59	63	67	78	77	70	68	44	36	676	56
1952	35	39	45	54	61	67	75	78	70	63		37*	624	
1953	36	41	49	57	61	67*	80	78		61	47	36	613	
1954	37	44	48	63	68	74	80	76	71	61	48	37	707	59
1955	34	36	46	54	61	69	76	79	70	60	46	40	671	56
1956	41	40	48	57	63	70	78	74	72	60	42	36	681	57
1957	38	45	52	57	61	67	73	75	68	59	44	38	677	56
1958	36	45	49	55	63	69	76	80	71	65	49	40	698	58
1959	37	45	52	65	74	82	83	74	70*				582	
1960										59	48	38*	145	
1961	34*	42*	51*	59	66	75	80*	79	67*	56*	43*	36*	690	58
1962	34*	40*	46	57*	60*	68*	76*	77	72	61	50*	40*	681	57
1963	34*	40	48*	50*	56*	58*	63*	67*	66*	63*	60*		605	55
1965	47*	45*	46*	45*	50*	56*	60*	56	74*	70*	61*	56*	666	56
1965	52*	50*	50*	50*	51*	55*	67*	68*		67*	52*	42*	604	
1966			58*	52	53	58	64	65	65	63*	57*	50*	385	
1967	44*	42*	46	47	52	57	64*	67*	68*	66	5[illegible]	48*	658	55
1968	45*	46*	48*	50*	57*	63*	66*	68*	68*	66*	59*	52*	680	57
Total	656	722	879	989	1,082	1,190	1,316	1,391	1,184	1,178	904	739	12,230	
Mean	39	42	49	55	60	66	73	73	70	62	50	41		57

*Based on Incomplete Records

Table 34
Temperature of Water
Colorado River near Grand Canyon, Arizona
(Unit: °F.)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	Mean
1941	41	46	51	55	63	69	76	77	68	58	41	40	685	57
1942	37	40	47	57	60	68	77	77	70				533	
1943										62	47	43	152	
1944	39	43	50	57	65	69	78	77	73	63	50	39	703	59
1945	39	44	48	56	64	66	72	76	69	62*	44*	36	676	56
1946	36	39	46	61	64	71	78	77	75	58	46	41	692	58
1947	35	43	52	58	65	68	76	77	73	62	46	39	694	58
1948	36	39	47	55	63	70	79	77	74	62	46	39	687	57
1949	36	37*	49*	59*	66*	71	79	78	74	60	50	40	699	58
1950	37	43	50	58	64	71	79	76	71	64	50	42	705	59
1951	39	42	50	59	65	71	79*	77	72	60	47*	38*	699	58
1952	37	41	46	57	65	71	78	79	71	63	50	38	696	58
1953	39	41	50	58	62	68	79	77	72	61	50	38	695	58
1954	38	45	50	62	69	72	80	77	72	62	50	40	717	60
1955	37	37	47	55	63	70	78	79	73	64	50	42	695	58
1956	44	43	50	59	67	73	78	75	75	63	45	37	709	59
1957	39	45	51	57	62	67	74	78	70	62	47	39	691	58
1958	37	45	48	56	63	70	76	79	71	63	49	39	696	58
1959	37	42	50	62	67	73	79	78	72	60	49	40	709	59
1960	36	41	50	58	65	73	80	79	75	62	50	40	709	59
1961	37	44	51	57	64	75	79	78	69	58	45	38	695	58
1962	35	40	45	56	60	69	74	77	73	62	53	43	687	57
1963	36	40	49	59	63	69	75	77	72	65	55	46	706	59
1964	44*	45	47	49	61	71	77	70	70	68	58	50	710	59
1965	50	49	50	52	54	58	69	70	68	65	60	53	698	58
1966	48	48	50	54	58	62	68	70	70	64	58	48	698	58
1967	45*	47*	50*	49*	57*	62*	69*	70*	69*	66*	59*	50*	693	58
1968	45*	48*	48*	52*	55*	63*	68*	70*	70*	66*	57*	54*	696	58
Total	1,059	1,157	1,322	1,527	1,694	1,860	2,054	2,052	1,931	1,685	1,352	1,132	18,825	
Mean	39	43	49	56	63	69	76	76	72	62	50	42		58

*Incomplete Record

Table 35
Temperature of Water
Virgin River at Littlefield, Arizona
(Unit: °F.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total	Mean
1947										60*	51	46	157	
1948	46	49	52	58	63	71	72	70	68	62	52	48	711	59
1949	42	46	55	60	64	72	72	69	68	61	54	47	710	59
1950	46	51	56	61	67	69	76	72	69	65	56	53	741	62
1951	49	54	58	66	66	70	73	72	69	64	55	48	744	62
1952	48	51	52	56	63	68	73	76	70	65	55	51	727	61
1953	51	53	58	63	67	70	79	74	70	62	57	49	753	63
1954	49	54	55	63	69	70	76	76	73	63	56	49	753	63
1955	48	49	55	61	65	69	73	75	71	62	55	51	734	61
1956	52	49	58	66	68	68	71	70	70	65	56	54	747	62
1957	54	58	63	68	63	68	74	71	66	61	52	49	747	62
1958	48	52	51	54	63	69	71	74	68	66	54	51	721	60
1959	50	51	57	67	69	72	77	74	69	64	55	51	756	63
1960	48	52	58	63	67	70	72	76	77	68	58	52	761	63
1961	53	59	64	71	77	81	81	79	71	68	58	52	814	68
1962	53	52	57	65	71	78	80	78	76	70	63	54	797	66
1963	51	60	63	69	76	75	79	79	75	71	59	50	807	67
1964	54	56	61	66	70	76	81	79	75	74	57	55	804	67
1965	56	57	62	63	68	76	81	82	74	69	58	48	794	66
1966	49	52	60	64	75	77	81	81	76	68	59	50	792	66
1967	51*	56*	62*	60*	68*	74	83*	82*	76*	72	59*	46	789	66
1968	48*	57	63	64*	66	79	82*	77*	77	70*	61	50*	794	66
Total	1,046	1,118	1,220	1,328	1,425	1,522	1,607	1,586	1,508	1,450	1,240	1,104		
Mean	50	53	58	63	68	72	76	75	72	66	56	50		63

*Incomplete Record.

Table 36
Temperature of Water
Colorado River below Hoover Dam, Arizona-Nevada
(Unit: °F.)

Year	Jan.	Feb.	Mar.	Apr.	May.	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	Mean
1941										64	63	60	187	
1942	57	56	55	55	56	58		59	60	61	62	61	640	
1943	57	55	55	56	56	56	57	58	69	60	63	60	692	58
1944	57	55	54	54	54	57	60	61	62	63*	64*	55*	696	58
1945	56*	55*	55*	56*	56*	57*	57*	63*	65*	63*	56*	57*	696	58*
1946	56*	55*	54*	54*	55*	55*	55*	55*	56*	56*	58*	57*	664	55*
1947	56*	55*	55*	54*	54*	55*	55*	55*	67*	68*	66*	59*	699	58*
1948	57*	55*	55*	55*	55*	59*	61*	62*	63*	63*	56*	54*	695	58*
1949	54*	52*	52*	52*	52*	55*	60*	61*	63*	65*	64*	56*	686	57*
1950	52*	52*	52*	52*	53*	54*	61*	60*	55*	56*	56*	56*	659	55*
1951	57*	55*	55*	55*	55*	56*	56*	56*	56*	56*	57*	57*	671	56*
1952	55*	55*	54*	54*	54*	58*	63*	64*	65*	66*	66*	58*	712	59*
1953	55*	55*	55*	55*	56*	57*	57*	57*	57*	58*	58*	58*	678	57*
1954	56*	56*	56*	56*	56*	56*	56*	57*	57*	57*	58*	58*	679	57*
1955	57*	55*	53*	53*	53*	54*	56*	55*	56*	58*	58*	58*	666	56*
1956	56*	55*	54*	53*	53*	55*	55*	55*	56*	56*	58*	58*	664	55*
1957	56*	54*	54*	54*	55*	56*	56*	56*	58*	59*	60*	60*	678	57*
1958	58*	56*	56*	55*	56*	56*	56*	56*	56*	56*	57*	57*	675	56*
1959	57*	56*	56*	56*	56*	56*	56*	56*	56*	56*	58*	56*	675	56*
1960	57*	55*	55*	54*	54*	54*	54*	54*	54*	54*	55*	55*	655	55*
1961	55*	55*	54*	54*	54*	55*	55*	55*	55*	55*	55*	55*	657	55*
1962	55*	54*	53*	53*	53*	53*	54*	54*	54*	54*	54*	54*	645	54*
1963	54*	54*	54*	54*	54*	56*	57*	57*	57*	56*	56*	56*	665	55*
1964	55*	54*	53*	55*	53*	54*	56*	56*	56*	56*	56*	56*	660	55*
1965	54*	54*	53*	53*	55*	54*	59*	56*	57*	56*	56*	56*	663	55*
1966	56*	56*	54*	54*	54*	54*	55*	55*	55*	54*	55*	55*	657	55*
1967	56*	55*	54*	54*	55*	55*	55*	56*	56*	55*	55*	55*	661	55
1968	55*	54*	54*	54*	54*	54*	55*	55*	54*	57*	57*	57*	660	55
Total	1,506	1,478	1,464	1,464	1,471	1,499	1,477	1,544	1,565	1,638	1,635	1,594	18,335	
Mean	56	55	54	54	54	56	57	57	58	58	58	57		56

*Incomplete Record

Table 37
Temperature of Water
Colorado River below Parker Dam, Arizona-California
(Unit: °F.)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug	Sept.	Oct.	Nov.	Dec.	Total	Mean
1954		56*	57	64	71	74	77	78	77	72	64	55	746	
1955	49	48	55	60	67	74	77*	82	78	72	64	57	783	65*
1956	54	52	56	64	69	75	77	79	78	74	62	53	793	66
1957	52	53	60	64	68	74	78	80	78	73	63	54	797	66
1958	52	57	59	64	71	73	77	79	78	74	64	57	805	67
1959	53	54	58	65	71	74	79	79	76	71	64	56	800	67
1960	51	52	57	65	66	68	68	75	74	70	64	53	763	64
1961	50	54	58	65	71	74	76	79	76	71	61	53	788	66
1962	50*	53	56	65	68	72	75	76	76	73	65	59	788	66*
1963	51*	52	58	63	67	72	75	79	80	74	66	56	793	66*
1964	50*	50	54	61	68	72	77	78	76	73	65	55	779	65*
1965	54	55	57	64	69	72	76	78	74	72	65	55	791	66
1966	51	52	56	65	70	74	76	77	74	72	63	55	785	65
1967	50*	52*	58	62	68*	72	77	78	78	72	68	57	792	66
1968	50*	55*	61	64	70	72*	75*	75*	77	72	64	54	789	66
Total	717	795	860	955	1,034	1,092	1,140	1,[illegible]2	1,150	1,085	962	830	11,792	
Mean	51	53	57	64	69	73	76	78	77	72	64	55		66

*Incomplete record.

Table 38
Temperature of Water
Colorado River at Imperial Dam, Arizona-California
(Unit: °F.)

Year	Jan.	Feb.	Mar.	Apr.	May.	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	Mean
1956	57*	54	61	67	74	81	84	84	82	72	57	51	824	69
1957	53	59	64	67	72	81	86	85	81	71	61	54	834	70
1958	52	57	60	67	77	80	84	86	82	74	61	55	835	70
1959	52	54	60	69	74	82	85	86	80	72	62	54	830	69
1960	54	54	62	68	74	80	83	84	81	72	61	53	826	69
1961	52	56	60	68	74	81	84	86	79	70	58	53	821	68
1962	51	58	58	70	74	80	84	84	83	73*	64	57	836	70
1963	51	58	62	67	75	79	84	85	83	76	62	54	836	70
1964	48	51	58	66	72	80	84	86	80	75	63*	55	818	68
1965	54	55	60	68	74	77	85	86	80	71	64*	54*	828	69
1966	50	51	59	68	75*	78	84	85	80	71*	63*	55*	819	68
1967	52	56*	62	64	72	78	85	86	81*	75	64*	52*	827	69
1968	52	57	64	68	75	82	86	84	82	72	64*	54*	840	70
Total	678	720	790	877	962	1,039	1,098	1,107	1,054	944	804	701	10,774	
Mean	52	55	61	67	74	80	84	85	81	73	62	54		69

*Incomplete Record

Table 39

Colorado River Basin

Historical Flow and Sedimentation Data

Green River near Jensen, Utah

Month	Flow (1,000 A.F.)	Weighted mean concentration (p.p.m.)	Load (1,000 tons)
Year 1949			
Jan.	53	100	7
Feb.	56	150	12
March	159	2,180	470
April	406	2,950	1,628
May	940	2,140	2,744
June	1,079	2,380	3,494
July	372	980	493
Aug.	111	360	54
Sept.	64	130	11
Oct.	119	1,670	269
Nov.	106	230	33
Dec.	64	120	11
Total	3,529	1,920	9,226
Year 1950			
Jan.	77	160	16
Feb.	72	350	34
March	208	2,640	747
April	531	5,020	3,624
May	843	2,460	2,822
June	1,202	1,500	2,447
July	577	880	688
Aug.	193	260	69
Sept.	106	920	132
Oct.	101	120	17
Nov.	107	180	26
Dec.	90	100	12
Total	4,107	1,900	10,634
Year 1951			
Jan.	70	110	11
Feb.	95	360	46
March	147	2,500	500
April	344	2,030	948
May	788	1,930	2,070
June	1,033	1,170	1,643
July	502	480	325
Aug.	275	1,190	446
Sept.	120	250	42
Oct.	138	2,470	465
Nov.	83	300	34
Dec.	74	60	6
Total	3,669	1,310	6,536
Year 1952			
Jan.	71	80	7
Feb.	74	130	13
March	91	350	44
April	773	6,780	7,142
May	1,421	2,370	4,582
June	1,199	1,290	2,106
July	326	670	300
Aug.	178	900	218
Sept.	93	200	26
Oct.	69	30	3
Nov.	58	60	4
Dec.	55	40	3
Total	4,408	2,410	14,448
Year 1953			
Jan.	73	90	9
Feb.	73	70	7
March	126	1,040	179
April	198	1,170	314
May	421	1,690	970
June	936	1,620	2,070
July	281	340	131
Aug.	143	640	125
Sept.	59	30	3
Oct.	53	30	2
Nov.	67	60	5
Dec.	56	60	5
Total	2,486	1,130	3,820
Year 1954			
Jan.	52	50	4
Feb.	73	180	18
March	115	530	84
April	255	1,170	407
May	572	1,600	1,249
June	332	1,080	488
July	307	840	350
Aug.	101	180	25
Sept.	72	1,200	117
Oct.	77	580	61
Nov.	72	100	9
Dec.	33	120	5
Total	2,061	1,000	2,817
Year 1955			
Jan.	37	70	4
Feb.	40	80	4
March	102	1,290	180
April	271	3,510	1,296
May	562	1,350	1,035
June	540	520	379
July	178	1,170	284
Aug.	112	4,430	673
Sept.	50	300	21
Oct.	51	100	7
Nov.	55	260	19
Dec.	76	1,160	121
Total	2,074	1,430	4,023
Year 1956			
Jan.	80	230	25
Feb.	50	110	7
March	272	9,290	3,437
April	454	1,680	1,039
May	918	1,960	2,452
June	992	1,170	1,581
July	252	240	81
Aug.	142	750	145
Sept.	61	90	8
Oct.	60	290	24
Nov.	62	260	22
Dec.	47	80	5
Total	3,390	1,910	8,826
Year 1957			
Jan.	46	60	3
Feb.	65	580	51
March	141	1,520	292
April	264	1,510	544
May	854	2,150	2,502
June	1,573	1,380	2,950
July	906	770	955
Aug.	236	770	246
Sept.	122	320	54
Oct.	122	130	22
Nov.	102	120	16
Dec.	75	140	13
Total	4,506	1,250	7,648
Year 1958			
Jan.	68	30	3
Feb.	102	520	72
March	153	940	196
April	356	1,930	935
May	1,103	1,690	2,528
June	805	800	881
July	142	180	35
Aug.	75	110	11
Sept.	54	200	15
Oct.	58	60	5
Nov.	70	70	6
Dec.	52	70	6
Total	3,038	1,140	4,693
Year 1959			
Jan.	47	60	4
Feb.	55	40	3
March	105	910	130
April	199	1,370	371
May	438	400	238
June	696	590	555
July	260	990	351
Aug.	127	1,110	192
Sept.	87	7,860	930
Oct.	123	4,210	705
Nov.	102	2,790	387
Dec.	56	110	8
Total	2,295	1,240	3,875
Year 1960			
Jan.	50	60	4
Feb.	52	70	5
March	272	8,050	2,978
April	468	2,070	1,320
May	492	1,330	891
June	554	1,030	778
July	129	150	26
Aug.	57	3,410	264
Sept.	38	160	8
Oct.	64	560	49
Nov.	77	120	13
Dec.	46	80	5
Total	2,299	2,030	6,341
Year 1961			
Jan.	46	60	4
Feb.	48	50	3
March	115	1,450	227
April	161	1,120	245
May	354	1,420	685
June	472	1,160	744
July	94	90	12
Aug.	62	2,750	232
Sept.	94	2,340	299
Oct.	148	990	199
Nov.	103	270	38
Dec.	71	190	18
Total	1,768	1,120	2,706
Year 1962			
Jan.	63	40	3
Feb.	260	13,360	4,723
March	273	16,820	6,246
April	914	6,170	7,667
May	1,050	1,750	2,495
June	820	1,270	1,418
July	451	780	481
Aug.	144	180	35
Sept.	58	130	10
Oct.	68	60	6
Nov.	35	20	1
Dec.	32	50	2
Total	4,168	4,070	23,088
Year 1963			
Jan.	46	100	6
Feb.	63	200	17
March	58	1,060	84
April	121	630	104
May	339	1,480	682
June	204	530	147
July	31	50	2
Aug.	28	5,170	197
Sept.	30	2,080	85
Oct.	21	140	4
Nov.	38	830	43
Dec.	64	460	40
Total	1,043	990	1,411
Year 1964			
Jan.	74	470	47
Feb.	76	370	38
March	63	310	27
April	147	3,190	638
May	538	2,470	1,811
June	486	810	537
July	255	500	172
Aug.	147	750	150
Sept.	142	240	46
Oct.	168	220	51
Nov.	158	210	46
Dec.	214	350	133
Total	2,468	1,100	3,696
Year 1965			
Jan.	259	710	250
Feb.	247	760	280
March	272	700	260
April	413	4,360	2,448
May	598	1,890	1,539
June	695	1,580	1,494
July	237	2,220	716
Aug.	164	1,140	162
Sept.	109	2,430	360
Oct.	157	510	104
Nov.	161	370	82
Dec.	159	360	77
Total	3,404	1,680	7,772
Year 1966			
Jan.	112	420	64
Feb.	104	440	62
March	246	4,230	1,415
April	322	1,430	627
May	418	1,080	612
June	257	580	202
July	131	210	38
Aug.	134	1,830	333
Sept.	133	370	67
Oct.	155	1,850	391
Nov.	114	280	43
Dec.	135	190	34
Total	2,261	1,260	3,888
Year 1967			
Jan.	163	240	53
Feb.	122	235	39
March	144	812	159
April	219	1300	388
May	463	1640	1030
June	676	940	869
July	319	570	247
Aug.	219	260	79
Sept.	204	380	105
Oct.	222	260	79
Nov.	204	120	34
Dec.	220	210	64
Total	3175	730	3146
Year 1968			
Jan.	218	170	51
Feb.	153	140	29
March	135	290	53
April	227	1440	445
May	617	1540	1297
June	782	850	907
July	344	280	129
Aug.	256	590	206
Sept.	202	90	24
Oct.	179	70	16
Nov.	182	80	19
Dec.	183	80	21
Total	3478	680	3197

Table 40

Colorado River Basin

Historical Flow and Sedimentation Data

Green River at Green River, Utah

Month	Flow (1,000 A.F.)	Weighted mean concentration (p.p.m.)	Load (1,000 tons)	Flow (1,000 A.F.)	Weighted mean concentration (p.p.m.)	Load (1,000 tons)
		Year 1941			Year 1947	
Jan.	100	420	57	92	670	84
Feb.	126	3,400	583	151	1,310	268
March	216	5,300	1,560	411	11,040	6,181
April	314	3,960	1,690	422	3,060	1,760
May	1,172	8,080	12,890	1,400	4,480	8,542
June	1,146	4,030	6,286	1,348	2,870	5,269
July	359	1,310	641	656	1,560	1,389
Aug.	267	12,130	4,416	365	6,910	3,439
Sept.	182	5,400	1,336	166	880	199
Oct.	318	6,900	2,986	181	1,870	461
Nov.	240	1,740	569	179	540	132
Dec.	168	430	99	152	360	74
Total	4,608	5,280	33,113	5,523	3,700	27,798
		Year 1942			Year 1948	
Jan.	112	590	91	141	230	44
Feb.	122	230	38	137	640	119
March	264	3,790	1,363	313	4,670	1,994
April	858	10,420	12,170	558	5,910	4,486
May	980	5,280	7,040	1,061	3,760	5,433
June	1,271	3,250	5,618	952	2,250	2,912
July	414	1,410	795	268	1,060	386
Aug.	152	580	120	137	3,590	671
Sept.	91	570	71	69	160	15
Oct.	118	1,280	205	92	1,100	139
Nov.	124	260	44	104	140	19
Dec.	116	230	36	97	190	25
Total	4,622	4,390	27,591	3,929	3,040	16,243
		Year 1943			Year 1949	
Jan.	112	150	23	100	300	41
Feb.	130	410	72	110	270	41
March	236	1,670	536	276	3,030	1,140
April	569	4,140	3,208	474	3,560	2,296
May	763	2,520	2,618	1,221	4,130	6,861
June	1,074	2,920	4,276	1,547	4,000	8,430
July	612	1,360	1,132	592	3,910	3,154
Aug.	300	8,070	3,298	172	1,030	242
Sept.	116	1,470	232	112	1,200	182
Oct.	124	2,600	439	207	3,960	1,115
Nov.	146	920	183	190	430	110
Dec.	112	240	37	128	160	28
Total	4,294	2,750	16,054	5,129	3,390	23,640
		Year 1944			Year 1950	
Jan.	80	300	32	141	270	51
Feb.	111	290	44	147	260	53
March	252	3,600	1,237	356	2,560	1,241
April	529	9,810	7,060	620	5,010	4,227
May	924	6,040	7,604	1,026	3,320	4,632
June	1,391	2,840	5,373	1,567	2,460	5,250
July	591	1,410	1,134	734	2,370	2,372
Aug.	143	390	75	246	300	100
Sept.	73	140	14	149	730	148
Oct.	115	570	89	153	220	46
Nov.	119	170	28	166	150	33
Dec.	88	90	11	171	140	33
Total	4,416	3,780	22,701	5,476	2,440	18,186
		Year 1945			Year 1951	
Jan.	109	100	15	113	100	15
Feb.	128	260	45	167	230	52
March	185	1,220	309	205	770	214
April	291	3,590	1,420	372	2,180	1,102
May	909	3,380	4,182	882	2,710	3,258
June	1,016	2,390	3,304	1,309	2,330	4,155
July	701	1,740	1,660	627	1,430	1,222
Aug.	335	4,750	2,169	379	7,800	4,019
Sept.	163	1,350	299	178	1,850	447
Oct.	161	800	175	211	3,880	1,111
Nov.	149	250	51	164	540	120
Dec.	113	210	32	132	270	48
Total	4,260	2,360	13,661	4,739	2,450	15,763
		Year 1946			Year 1952	
Jan.	123	180	30	134	240	43
Feb.	117	340	54	140	260	50
March	236	1,200	385	160	430	94
April	528	3,460	2,491	988	8,450	11,360
May	775	2,190	2,308	2,087	4,280	12,160
June	746	1,860	1,888	1,809	1,780	4,392
July	264	540	193	514	960	673
Aug.	152	6,540	1,354	315	4,100	1,758
Sept.	105	3,090	440	184	2,230	559
Oct.	149	3,820	774	129	70	13
Nov.	170	1,800	418	122	90	15
Dec.	154	640	135	129	130	23
Total	3,519	2,190	10,470	6,711	3,410	31,140

Month	Flow (1,000 A.F.)	Weighted mean concentration (p.p.m.)	Load (1,000 tons)	Flow (1,000 A.F.)	Weighted mean concentration (p.p.m.)	Load (1,000 tons)
		Year 1953			Year 1959	
Jan.	140	100	19	97	90	12
Feb.	141	120	24	114	140	21
March	217	880	259	146	330	66
April	221	670	201	219	1,120	334
May	454	1,760	1,090	480	1,010	661
June	1,167	2,920	4,646	763	1,390	1,446
July	376	770	395	346	1,300	612
Aug.	212	3,950	1,137	180	8,950	2,192
Sept.	87	270	32	104	2,200	311
Oct.	86	340	40	178	4,010	972
Nov.	125	230	39	152	690	143
Dec.	107	260	37	106	190	28
Total	3,333	1,750	7,919	2,885	1,730	6,798
		Year 1954			Year 1960	
Jan.	107	220	32	95	270	35
Feb.	138	470	88	102	170	23
March	169	710	164	320	6,470	2,815
April	270	1,610	591	534	2,880	2,091
May	640	2,450	2,130	551	1,420	1,067
June	376	780	401	682	1,320	1,228
July	346	2,220	1,034	170	250	58
Aug.	120	1,940	316	69	920	86
Sept.	134	13,750	2,509	59	1,810	145
Oct.	139	8,960	1,690	96	3,260	425
Nov.	120	490	80	105	240	35
Dec.	80	280	31	80	230	25
Total	2,639	2,530	9,066	2,863	2,060	8,033
		Year 1955			Year 1961	
Jan.	80	520	57	79	150	16
Feb.	86	310	36	94	150	19
March	237	5,980	1,933	136	600	111
April	311	3,720	1,574	184	1,090	274
May	677	3,320	3,060	342	1,370	639
June	654	1,740	1,552	542	1,160	856
July	223	590	180	112	540	83
Aug.	161	5,550	1,215	80	6,210	676
Sept.	71	2,020	194	175	18,500	4,403
Oct.	77	220	23	234	5,380	1,713
Nov.	86	230	27	161	840	183
Dec.	127	410	71	126	520	90
Total	2,790	2,610	9,922	2,265	2,940	9,063
		Year 1956			Year 1962	
Jan.	155	610	128	114	980	152
Feb.	100	310	42	403	7,420	4,066
March	314	7,220	3,087	401	10,720	5,848
April	460	3,110	1,946	1,093	8,470	12,587
May	995	3,820	5,175	1,350	3,960	7,277
June	1,207	2,720	4,463	1,074	1,920	2,801
July	294	700	281	598	1,230	1,003
Aug.	169	2,480	570	176	240	58
Sept.	72	120	12	98	12,690	1,691
Oct.	77	670	70	126	4,450	763
Nov.	99	430	58	94	180	23
Dec.	79	170	18	72	130	13
Total	4,021	2,900	15,850	5,599	4,760	36,282
		Year 1957			Year 1963	
Jan.	83	130	14	71	270	26
Feb.	100	250	34	120	1,550	253
March	237	1,630	526	99	470	63
April	290	1,700	672	154	960	200
May	913	3,880	4,817	399	1,710	930
June	1,871	3,030	7,722	310	720	302
July	1,164	2,330	3,698	51	130	9
Aug.	386	8,300	4,364	72	14,110	1,382
Sept.	202	5,870	1,613	95	13,630	1,761
Oct.	185	1,180	297	47	3,070	196
Nov.	228	2,890	896	74	860	87
Dec.	149	490	100	84	3,270	374
Total	5,808	3,130	24,753	1,576	2,600	5,583
		Year 1958			Year 1964	
Jan.	128	240	42	109	1,170	173
Feb.	183	1,320	331	114	2,650	411
March	246	1,580	529	128	1,290	225
April	432	3,660	2,151	190	3,910	1,010
May	1,311	4,570	8,151	634	6,370	5,491
June	1,174	2,440	3,989	725	2,190	2,160
July	224	300	90	344	990	464
Aug.	110	470	70	196	7,430	1,981
Sept.	96	1,660	217	140	1,820	346
Oct.	91	130	16	196	370	98
Nov.	102	90	12	200	280	75
Dec.	114	160	25	267	450	162
Total	4,211	2,730	15,623	3,243	2,860	12,596

TABLE 40
COLORADO RIVER BASIN
HISTORICAL FLOW AND SEDIMENTATION DATA

For Green River at Green River, Utah

Month	Flow (1,000 A.F.)	Weighted mean concentration (p.p.m.)	Load (1,000 tons)	Flow (1,000 A.F.)	Weighted mean concentration (p.p.m.)	Load (1,000 tons)
		Year 1965			Year 1968	
Jan.	300	300	124	249	120	42
Feb.	303	540	222	196	600	161
March	361	2,110	1,034	241	590	195
April	518	3,300	2,327	275	1,440	538
May	819	3,130	3,486	708	1,600	1,540
June	1,207	3,530	5,804	1,248	1,570	2,662
July	546	3,440	2,555	426	640	372
Aug.	228	4,510	1,399	345	4,670	2,193
Sept.	189	2,320	596	241	160	52
Oct.	253	1,120	384	230	310	96
Nov.	239	360	117	221	70	20
Dec.	248	420	143	209	140	39
Total	5,211	2,570	18,191	4,589	1,270	7,910
		Year 1966			Year	
Jan.	181	200	50			
Feb.	166	150	35			
March	393	5,110	2,730			
April	390	1,090	579			
May	566	1,450	1,115			
June	325	610	269			
July	146	740	148			
Aug.	146	2,200	437			
Sept.	157	2,070	442			
Oct.	193	1,260	332			
Nov.	158	1,660	357			
Dec.	148	4,090	823			
Total	2,969	1,810	7,317			
		Year 1967			Year	
Jan.	196	430	115			
Feb.	169	400	93			
March	256	1,440	503			
April	260	700	248			
May	504	2,850	1,952			
June	1,134	3,630	5,602			
July	508	2,270	1,571			
Aug.	247	1,910	641			
Sept.	231	1,790	561			
Oct.	250	450	152			
Nov.	243	120	39			
Dec.	229	120	36			
Total	4,227	2,000	11,513			

Table 41

Colorado River Basin

Historical Flow and Sedimentation Datc

Colorado River near Cisco, Utah

Month	Flow (1,000 A.F.)	Weighted mean concentration (p.p.m.)	Load (1,000 tons)
	Year 1942		
Jan.	181	300	74
Feb.	166	400	90
March	228	2,200	684
April	1,344	7,000	12,800
May	1,809	2,700	6,650
June	1,961	900	2,400
July	579	600	473
Aug.	185	200	50
Sept.	134	300	55
Oct.	162	260	57
Nov.	186	170	42
Dec.	164	100	21
Total	7,099	2,420	23,396
	Year 1943		
Jan.	153	150	31
Feb.	146	230	46
March	174	260	62
April	709	1,430	1,380
May	996	980	1,330
June	1,365	690	1,280
July	502	580	398
Aug.	368	6,170	3,090
Sept.	212	1,510	435
Oct.	184	250	62
Nov.	215	1,420	417
Dec.	190	170	45
Total	5,214	1,210	8,576
	Year 1944		
Jan.	140	270	52
Feb.	152	440	91
March	166	380	87
April	304	3,830	1,581
May	1,784	3,950	9,582
June	1,843	1,350	3,376
July	677	780	720
Aug.	149	170	35
Sept.	99	170	23
Oct.	159	240	53
Nov.	196	290	78
Dec.	171	100	24
Total	5,840	1,980	15,702
	Year 1945		
Jan.	149	100	20
Feb.	151	540	111
March	178	270	64
April	329	1,450	648
May	1,495	1,270	2,582
June	1,311	320	567
July	676	600	549
Aug.	446	4,560	2,773
Sept.	146	200	41
Oct.	217	890	262
Nov.	224	270	84
Dec.	183	240	58
Total	5,505	1,040	7,759
	Year 1946		
Jan.	174	200	46
Feb.	155	520	109
March	191	390	101
April	525	3,170	2,267
May	726	700	693
June	1,027	1,030	1,438
July	309	320	136
Aug.	196	10,200	2,717
Sept.	135	570	106
Oct.	206	900	253
Nov.	206	700	197
Dec.	208	300	85
Total	4,058	1,470	8,148
	Year 1947		
Jan.	145	400	79
Feb.	151	600	123
March	189	900	232
April	316	2,160	930
May	1,423	2,940	5,697
June	1,594	1,190	2,590
July	985	820	1,092
Aug.	369	4,520	2,274
Sept.	259	1,830	647
Oct.	328	5,230	2,338
Nov.	277	360	136
Dec.	223	440	134
Tptal	6,259	1,910	16,272

Flow (1,000 A.F.)	Weighted mean concentration (p.p.m.)	Load (1,000 tons)
Year 1948		
191	360	94
210	2,130	610
245	1,350	449
830	4,280	4,832
1,959	1,580	4,216
1,499	670	1,373
446	220	133
225	2,020	619
121	310	52
175	310	74
204	60	16
186	110	28
6,291	1,460	12,496
Year 1949		
188	160	40
187	1,530	389
243	1,430	474
615	2,600	2,181
1,289	1,060	1,862
1,910	660	1,706
908	350	430
224	2,840	866
158	1,400	301
225	1,340	412
210	140	41
180	120	30
6,337	1,010	8,732
Year 1950		
199	280	76
201	650	179
209	320	91
541	2,040	1,505
764	1,010	1,048
1,113	690	1,045
347	570	268
109	150	22
138	1,270	239
125	130	23
161	450	98
167	70	16
4,074	830	4,610
Year 1951		
153	100	21
151	270	56
161	170	38
173	340	81
758	1,740	1,790
1,173	690	1,108
530	400	292
238	4,930	1,598
131	1,110	196
169	810	186
178	110	27
172	430	101
3,987	1,010	5,494
Year 1952		
191	470	123
156	730	154
194	1,490	394
969	3,830	5,047
2,152	1,560	4,563
2,314	1,010	3,171
641	1,230	1,077
358	1,040	506
213	260	77
166	50	11
177	50	11
188	60	14
7,719	1,440	15,148
Year 1953		
185	50	13
142	20	5
187	70	17
250	630	214
606	1,740	1,435
1,399	690	1,321
353	410	198
256	5,770	2,011
128	180	32
177	5,550	1,340
207	640	179
171	150	34
4,061	1,230	6,799

Month	Flow (1,000 A.F.)	Weighted mean concentration (p.p.m.)	Load (1,000 tons)
	Year 1954		
Jan.	177	170	40
Feb.	143	160	32
March	161	220	47
April	221	610	184
May	436	1,240	735
June	217	290	85
July	150	780	160
Aug.	98	2,060	276
Sept.	171	7,510	1,752
Oct.	215	3,280	962
Nov.	164	690	154
Dec.	140	240	46
Total	2,293	1,430	4,473
	Year 1955		
Jan.	134	260	47
Feb.	121	510	84
March	198	4,540	1,222
April	321	3,020	1,315
May	752	3,360	3,434
June	689	1,300	1,215
July	214	820	239
Aug.	185	4,710	1,187
Sept.	108	440	65
Oct.	119	40	7
Nov.	169	680	156
Dec.	176	130	30
Total	3,186	2,080	9,001
	Year 1956		
Jan.	155	190	40
Feb.	141	190	37
March	187	1,010	258
April	356	1,850	896
May	1,005	2,130	2,910
June	924	980	1,239
July	172	1,500	352
Aug.	119	4,370	706
Sept.	81	90	10
Oct.	121	380	62
Nov.	165	150	33
Dec.	142	130	26
Total	3,568	1,350	6,569
	Year 1957		
Jan.	164	640	142
Feb.	168	2,100	479
March	167	330	75
April	398	2,610	1,411
May	1,375	2,630	4,920
June	2,859	1,650	6,439
July	1,952	1,360	3,603
Aug.	661	3,990	3,588
Sept.	314	1,790	765
Oct.	292	3,170	1,257
Nov.	300	1,260	513
Dec.	239	90	29
Total	8,889	1,920	23,221
	Year 1958		
Jan.	200	130	35
Feb.	225	460	142
March	254	790	272
April	756	3,750	3,856
May	2,032	2,140	5,904
June	1,560	920	1,962
July	234	180	56
Aug.	109	850	126
Sept.	153	1,060	220
Oct.	155	120	25
Nov.	190	130	34
Dec.	176	50	13
Total	6,044	1,540	12,645
	Year 1959		
Jan.	168	70	16
Feb.	153	90	19
March	150	10	3
April	163	390	87
May	536	1,530	1,114
June	924	1,080	1,362
July	214	130	37
Aug.	160	2,790	604
Sept.	124	880	149
Oct.	250	1,360	464
Nov.	210	1,130	322
Dec.	163	40	9
Total	3,215	960	4,186

Flow (1,000 A.F.)	Weighted mean concentration (p.p.m.)	Load (1,000 tons)
Year 1960		
164	120	26
143	110	22
273	3,120	1,160
629	2,580	2,205
758	990	1,024
1,068	710	1,034
251	100	33
106	120	17
117	140	22
153	270	57
177	160	38
165	40	9
4,004	1,050	5,725
Year 1961		
156	30	7
140	70	14
162	110	24
206	590	165
677	870	799
664	340	307
130	230	40
138	1,950	366
316	5,440	2,340
357	2,270	1,101
252	150	53
197	170	45
3,395	1,140	5,261
Year 1962		
182	520	129
261	2,700	957
246	540	182
1,054	3,260	4,677
1,603	1,370	2,984
1,400	810	1,548
765	790	818
206	90	25
173	3,260	768
262	440	156
243	70	24
180	100	25
6,575	1,370	12,293
Year 1963		
163	110	25
193	990	261
219	1,250	373
245	1,040	347
517	800	561
332	470	213
114	1,150	178
168	6,960	1,591
183	4,330	1,078
134	450	82
179	370	89
138	260	48
2,585	1,380	4,846
Year 1964		
132	390	70
121	410	68
128	120	21
214	1,620	473
861	4,100	4,804
780	950	1,008
276	1,010	379
241	8,710	2,855
153	500	104
164	50	11
182	90	22
181	550	135
3,433	2,130	9,950
Year 1965		
162	200	44
140	240	45
154	240	50
562	4,140	3,168
1,272	2,550	4,413
1,654	1,270	2,864
1,116	2,740	4,163
447	2,810	1,707
369	1,580	791
360	2,070	1,013
249	870	295
237	430	138
6,722	2,040	18,691

TABLE 41
COLORADO RIVER BASIN
HISTORICAL FLOW AND SEDIMENTATION DATA

For Colorado River near Cisco, Utah

Month	Flow (1,000 A.F.)	Weighted mean concentration (p.p.m.)	Load (1,000 tons)	Flow (1,000 A.F.)	Weighted mean concentration (p.p.m.)	Load (1,000 tons)
		Year 1966			Year	
Jan.	200	640	174			
Feb.	169	400	92			
March	278	2,220	838			
April	438	2,240	1,337			
May	697	1,200	1,141			
June	429	410	237			
July	185	250	63			
Aug.	120	200	32			
Sept.	145	650	129			
Oct.	175	230	55			
Nov.	153	110	23			
Dec.	174	4,400	1,041			
Total	3,163	1,200	5,162			
		Year 1967			Year	
Jan.	146	140	27			
Feb.	136	140	26			
March	185	210	53			
April	198	260	69			
May	462	2,620	1,645			
June	713	2,250	2,182			
July	327	2,580	1,147			
Aug.	175	7,520	1,791			
Sept.	178	1,620	393			
Oct.	174	180	43			
Nov.	211	200	58			
Dec.	241	590	194			
Total	3,146	1,780	7,628			
		Year 1968			Year	
Jan.	205	380	107			
Feb.	193	740	195			
March	171	270	62			
April	230	1,890	591			
May	667	3,040	2,763			
June	1,171	1,560	2,481			
July	306	1,360	565			
Aug.	365	9,140	4,537			
Sept.	159	80	18			
Oct.	213	350	101			
Nov.	257	210	73			
Dec.	248	80	28			
Total	4,185	2,020	11,521			

Table 42

Colorado River Basin

Historical Flow and Sedimentation Data

San Juan River near Bluff, Utah

Month	Flow (1,000 A.F.)	Weighted mean concentration (p.p.m.)	Load (1,000 tons)	Flow (1,000 A.F.)	Weighted mean concentration (p.p.m.)	Load (1,000 tons)
	Year [illegible]			Year [illegible]		
Jan.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Feb.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
March	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
April	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
May	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
June	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
July	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Aug.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Sept.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Oct.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Nov.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Dec.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Year [illegible]			Year [illegible]		
Jan.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Feb.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
March	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
April	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
May	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
June	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
July	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Aug.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Sept.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Oct.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Nov.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Dec.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Year [illegible]			Year [illegible]		
Jan.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Feb.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
March	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
April	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
May	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
June	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
July	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Aug.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Sept.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Oct.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Nov.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Dec.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Year [illegible]			Year [illegible]		
Jan.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Feb.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
March	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
April	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
May	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
June	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
July	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Aug.	[illegible]	[illegible]	[illegible]	[illegible]	7,010	40
Sept.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Oct.	[illegible]	[illegible]	[illegible]	[illegible]	1,330	54
Nov.	[illegible]	[illegible]	[illegible]	25	960	71
Dec.	[illegible]	[illegible]	[illegible]	[illegible]	470	21
Total	[illegible]	[illegible]	[illegible]	854	3,850	4,475
	Year [illegible]			Year 1951		
Jan.	[illegible]	[illegible]	[illegible]	[illegible]	300	[illegible]
Feb.	[illegible]	[illegible]	351	[illegible]	[illegible]	[illegible]
March	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
April	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	30
May	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
June	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
July	[illegible]	[illegible]	[illegible]	[illegible]	300	8
Aug.	[illegible]	[illegible]	[illegible]	[illegible]	17,300	[illegible]
Sept.	[illegible]	[illegible]	178	[illegible]	[illegible]	[illegible]
Oct.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Nov.	[illegible]	[illegible]	177	[illegible]	7,250	390
Dec.	[illegible]	[illegible]	145	[illegible]	[illegible]	510
Total	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5,505
	Year [illegible]			Year [illegible]		
Jan.	47	2,440	125	88	18,380	[illegible]
Feb.	36	[illegible]	440	40	[illegible]	150
March	47	[illegible]	172	87	17,290	2,044
April	95	4,300	554	[illegible]	12,170	7,494
May	125	2,580	440	618	5,690	4,786
June	204	3,730	1,034	769	4,910	5,140
July	63	11,770	1,015	238	5,490	1,778
Aug.	75	32,620	3,406	83	6,300	715
Sept.	44	7,690	462	56	31,220	2,397
Oct.	55	4,120	309	36	3,110	152
Nov.	60	3,720	305	41	3,490	193
Dec.	46	1,420	88	43	3,090	183
Total	887	6,890	8,310	2,554	7,850	27,240

Month	Flow (1,000 A.F.)	Weighted mean concentration (p.p.m.)	Load (1,000 tons)	Flow (1,000 A.F.)	Weighted mean concentration (p.p.m.)	Load (1,000 tons)
	Year [illegible]			Year [illegible]		
Jan.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Feb.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
March	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
April	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
May	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
June	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
July	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Aug.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Sept.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Oct.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Nov.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Dec.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Year [illegible]			Year [illegible]		
Jan.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Feb.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
March	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
April	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
May	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
June	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
July	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Aug.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Sept.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Oct.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Nov.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Dec.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Year [illegible]			Year [illegible]		
Jan.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Feb.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
March	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
April	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
May	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
June	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
July	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Aug.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Sept.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Oct.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Nov.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Dec.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Year [illegible]			Year [illegible]		
Jan.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Feb.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
March	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
April	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
May	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
June	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
July	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Aug.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Sept.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Oct.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Nov.	[illegible]	[illegible]	[illegible]	[illegible]	1,190	118
Dec.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Year [illegible]			Year [illegible]		
Jan.	[illegible]	[illegible]	[illegible]	[illegible]	410	[illegible]
Feb.	[illegible]	[illegible]	[illegible]	[illegible]	1,590	[illegible]
March	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
April	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
May	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
June	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
July	[illegible]	7,100	2,861	[illegible]	[illegible]	[illegible]
Aug.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Sept.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Oct.	[illegible]	[illegible]	[illegible]	41	[illegible]	[illegible]
Nov.	141	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Dec.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total	[illegible]	10,400	[illegible]	[illegible]	11,250	[illegible]
	Year [illegible]			Year [illegible]		
Jan.	[illegible]	14,010	101	[illegible]	[illegible]	148
Feb.	119	[illegible]	[illegible]	[illegible]	[illegible]	38
March	[illegible]	12,380	[illegible]	[illegible]	[illegible]	[illegible]
April	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
May	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
June	[illegible]	[illegible]	[illegible]	121	[illegible]	[illegible]
July	[illegible]	[illegible]	251	[illegible]	[illegible]	[illegible]
Aug.	[illegible]	[illegible]	[illegible]	131	[illegible]	[illegible]
Sept.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1,840
Oct.	47	[illegible]	[illegible]	37	[illegible]	95
Nov.	43	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Dec.	36	750	38	[illegible]	[illegible]	[illegible]
Total	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE 42
COLORADO RIVER BASIN
HISTORICAL FLOW AND SEDIMENTATION DATA

For San Juan River near Bluff, Utah

Month	Flow (1,000 A.F.)	Weighted mean concentration (p.p.m.)	Load (1,000 tons)	Flow (1,000 A.F.)	Weighted mean concentration (p.p.m.)	Load (1,000 tons)
		Year 1965			Year 1968	
Jan.	122	9,510	1,578	36	2,370	113
Feb.	120	6,470	1,056	54	5,040	370
March	85	6,660	770	50	3,910	266
April	165	17,560	3,943	83	6,750	762
May	288	22,740	8,910	148	6,550	1,319
June	419	6,050	3,448	240	7,730	2,533
July	295	5,870	2,355	82	15,130	1,687
Aug.	218	35,900	10,650	176	53,150	12,722
Sept.	177	6,570	1,583	41	6,060	338
Oct.	190	5,140	1,328	56	3,390	258
Nov.	232	5,420	1,712	49	1,800	120
Dec.	235	6,610	2,115	45	770	47
Total	2,546	11,480	39,448	1,060	14,240	20,535
		Year 1966			Year	
Jan.	198	3,230	869			
Feb.	129	2,070	363			
March	199	6,940	1,878			
April	252	3,020	1,036			
May	267	2,460	894			
June	127	1,810	312			
July	54	6,530	480			
Aug.	44	23,770	1,423			
Sept.	43	12,320	721			
Oct.	95	4,030	521			
Nov.	70	2,030	193			
Dec.	72	7,690	753			
Total	1,550	4,480	9,443			
		Year 1967			Year	
Jan.	58	810	64			
Feb.	64	2,040	178			
March	79	1,540	166			
April	31	400	17			
May	78	4,120	437			
June	89	8,070	977			
July	39	15,330	813			
Aug.	151	47,130	9,679			
Sept.	94	25,880	3,308			
Oct.	31	7,800	329			
Nov.	38	9,150	473			
Dec.	39	3,040	161			
Total	791	15,430	16,602			

Table 43

Colorado River Basin

Historical Flow and Sedimentation Data

Colorado River at Lees Ferry, Arizona

Month	Flow (1,000 A.F.)	Weighted mean concentration (p.p.m.)	Load (1,000 tons)	Flow (1,000 A.F.)	Weighted mean concentration (p.p.m.)	Load (1,000 tons)	Month	Flow (1,000 A.F.)	Weighted mean concentration (p.p.m.)	Load (1,000 tons)	Flow (1,000 A.F.)	Weighted mean concentration (p.p.m.)	Load (1,000 tons)
		Year 1946			Year 1952				Year 1958			Year 1964	
Jan.	330	1,830	820	476	5,500	4,440	Jan.	397	1,340	721	71	560	54
Feb.	335	2,920	1,321	379	1,740	896	Feb.	536	3,920	2,882	231	1,100	345
March	516	6,540	4,595	460	2,850	1,708	March	696	4,200	3,972	389	2,410	1,272
April	1,480	5,680	11,220	2,267	9,510	29,650	April	1,576	7,870	16,865	771	2,000	2,092
May	2,158	3,770	11,070	5,080	5,120	35,390	May	3,966	6,620	35,934	319	1,620	616
June	2,729	4,610	17,130	5,192	3,330	23,530	June	3,678	4,600	23,022	60	20	2
July	1,429	1,860	3,614	1,571	2,000	4,293	July	628	1,000	854	60	20	2
Aug.	795	7,360	7,963	821	4,400	4,812	Aug.	286	1,310	1,137	174	50	12
Sept.	443	3,870	2,358	542	6,510	4,805	Sept.	320	5,550	2,415	146	10	3
Oct.	378	4,030	2,172	329	1,030	519	Oct.	311	1,290	544	252	30	10
Nov.	456	2,560	1,621	386	1,300	692	Nov.	357	1,310	879	328	70	31
Dec.	396	1,730	908	379	1,240	640	Dec.	366	1,370	700	300	50	41
Total	11,414	4,180	62,734	17,926	4,540	110,456	Total	13,141	5,070	92,504	3,266	1,060	4,482
		Year 1947			Year 1953				Year 1959			Year 1965	
Jan.	278	1,230	462	304	1,220	466	Jan.	315	1,490	[illegible]	558	310	233
Feb.	344	1,430	717	326	1,150	509	Feb.	315	1,140	[illegible]	515	410	288
March	509	1,910	2,709	458	1,460	908	March	354	[illegible]	[illegible]	516	380	663
April	1,027	8,280	11,570	329	1,330	1,101	April	420	[illegible]	[illegible]	1,221	1,280	2,056
May	3,251	6,820	30,160	1,047	3,370	4,810	May	1,025	1,380	[illegible]	2,884	570	1,203
June	4,136	3,600	20,266	2,995	3,540	14,430	June	1,836	1,100	[illegible]	2,303	420	1,322
July	1,782	2,350	5,62[illegible]	950	3,090	3,993	July	782	[illegible]	[illegible]	[illegible]	[illegible]	11
Aug.	417	1,320	748	661	13,080	11,720	Aug.	[illegible]	[illegible]	[illegible]	571	[illegible]	12
Sept.	289	640	200	258	4,110	1,442	Sept.	246	[illegible]	[illegible]	[illegible]	[illegible]	10
Oct.	348		*3,300	321	6,010	2,622	Oct.	315	[illegible]	[illegible]	[illegible]		*10
Nov.	384		*750	414	3,240	1,822	Nov.	400	[illegible]	[illegible]	[illegible]		*1[illegible]
Dec.	320		*450	341	1,650	765	Dec.	352	[illegible]	[illegible]	531		*10
Total	13,019	4,350	77,3[illegible]	8,730	3,780	44,852	Total	7,061	[illegible]	[illegible]	[illegible]	[illegible]	5,5[illegible]
		Year 1948			Year 1954				Year 1960			Year	
Jan.	406	2,040	1,127	318	1,730	748	Jan.	305	[illegible]	[illegible]			
Feb.	458	4,250	2,649	342	1,770	825	Feb.	318	[illegible]	[illegible]			
March	645	5,550	4,877	393	2,090	1,118	March	765	[illegible]	[illegible]			
April	1,703	9,280	21,510	546	2,700	2,008	April	1,610	3,150	[illegible]			
May	3,507	5,600	26,740	1,277	4,340	7,550	May	1,524	[illegible]	[illegible]			
June	3,339	3,920	17,820	792	2,360	2,547	June	2,220	[illegible]	[illegible]			
July	980	1,830	2,419	647	6,360	5,603	July	567	[illegible]	[illegible]			
Aug.	531	9,190	6,644	321	4,000	1,749	Aug.	208	[illegible]	[illegible]			
Sept.	280	3,380	807	389	13,530	7,163	Sept.	193	[illegible]	[illegible]			
Oct.	331	4,010	1,804	512	13,540	9,443	Oct.	341	[illegible]	[illegible]			
Nov.	408	6,100	3,386	349	2,100	997	Nov.	345	[illegible]	[illegible]			
Dec.	347	1,850	875	278	1,210	459	Dec.	275	[illegible]	[illegible]			
Total	12,985	5,170	90,678	6,164	4,800	40,210	Total	8,790	[illegible]	[illegible]			
		Year 1949			Year 1955				Year 1961			Year	
Jan.	337	3,500	1,607	244	1,110	369	Jan.	266	[illegible]	[illegible]			
Feb.	361	4,580	2,251	243	1,120	370	Feb.	331	1,55[illegible]	[illegible]			
March	705	5,920	5,689	580	8,010	6,321	March	365	1,6[illegible]	[illegible]			
April	1,307	6,650	11,860	617	4,830	4,060	April	557	[illegible]	[illegible]			
May	3,068	5,040	22,110	1,570	6,090	13,020	May	1,115	[illegible]	[illegible]			
June	4,419	5,220	31,390	1,586	3,750	8,107	June	1,585	[illegible]	[illegible]			
July	2,137	3,980	11,540	571	2,660	2,055	July	369	[illegible]	[illegible]			
Aug.	576	4,120	3,256	510	16,030	11,120	Aug.	337	14,7[illegible]	[illegible]			
Sept.	313	2,290	975	230	5,450	1,705	Sept.	711	17,0[illegible]	[illegible]			
Oct.	509	5,390	3,730	214	1,130	330	Oct.	725	[illegible]	[illegible]			
Nov.	473	1,720	1,115	275	1,530	572	Nov.	527	2,7[illegible]	1,28[illegible]			
Dec.	368	1,190	598	326	1,700	755	Dec.	380	1,010	775			
Total	14,684	4,790	95,136	6,966	5,150	47,7[illegible]	Total	7,316	4,350	43,414			
		Year 1950			Year 1956				Year 1962			Year	
Jan.	350	1,630	776	273	1,950	580	Jan.	349	1,450	703			
Feb.	398	1,660	900	290	1,320	385	Feb.	791	9,060	9,749			
March	650	2,990	2,649	511	5,100	3,542	March	598	4,000	3,225			
April	1,217	5,150	8,533	808	5,700	7,098	April	2,391	6,645	21,547			
May	1,971	3,800	10,610	2,198	5,180	15,270	May	1,633	1,880	8,470			
June	2,979	3,170	12,840	2,594	4,650	16,410	June	2,876	826	3,240			
July	1,377	4,630	8,680	557	1,960	1,484	July	1,717	1,160	2,714			
Aug.	422	1,290	742	356	7,200	3,768	Aug.	469	1,050	666			
Sept.	330	5,060	2,275	166	520	140	Sept.	317	6,000	2,570			
Oct.	342	1,320	615	187	610	154	Oct.	539	14,360	10,522			
Nov.	350	1,090	520	300	2,110	863	Nov.	428	3,170	1,806			
Dec.	415	1,190	670	247	850	280	Dec.	333	2,100	951			
Total	10,801	3,390	49,863	8,659	4,300	50,585	Total	14,439	3,400	67,256			
		Year 1951			Year 1957				Year 1963			Year	
Jan.	315	900	384	284	1,450	562	Jan.	169	1,860	427			
Feb.	361	1,240	608	323	3,080	1,358	Feb.	369	2,550	1,275			
March	417	1,070	609	499	2,860	1,944	March	188	1,080	276			
April	531	2,120	1,536	828	4,560	5,136	April	60	40	3			
May	1,645	3,920	8,782	2,569	6,140	21,450	May	62	40	3			
June	2,886	3,390	13,300	5,642	4,470	34,350	June	140	420	81			
July	1,357	1,640	3,021	4,015	3,910	21,330	July	90	330	40			
Aug.	787	12,720	13,630	1,604	9,080	19,800	Aug.	62	110	9			
Sept.	411	7,580	4,235	822	11,630	13,000	Sept.	60	110	9			
Oct.	412	5,460	3,064	748	13,030	13,254	Oct.	61	100	8			
Nov.	445	4,000	2,423	848	8,490	9,791	Nov.	60	120	10			
Dec.	333	1,530	696	517	1,870	1,316	Dec.	63	130	11			
Total	9,900	3,880	52,288	18,702	5,630	143,301	Total	1,384	1,140	2,155			

*Estimated

Table 44

Colorado River Basin

Historical Flow and Sedimentation Data

Colorado River near Grand Canyon, Arizona

Month	Flow (1,000 A.F.)	Weighted mean concentration (p.p.m.)	Load (1,000 tons)	Flow (1,000 A.F.)	Weighted mean concentration (p.p.m.)	Load (1,000 tons)	Month	Flow (1,000 A.F.)	Weighted mean concentration (p.p.m.)	Load (1,000 tons)	Flow (1,000 A.F.)	Weighted mean concentration (p.p.m.)	Load (1,000 tons)
		Year 1941			Year 1947				Year 1953			Year 1959	
Jan.	434	9,320	5,499	303	550	228	Jan.	408	340	190	334	590	270
Feb.	515	12,640	8,851	371	1,120	563	Feb.	378	330	168	326	680	300
March	838	18,520	21,110	653	8,430	7,489	March	478	900	586	365	1,610	800
April	1,209	13,930	22,910	785	5,530	5,907	April	533	860	624	423	410	237
May	4,976	14,000	94,760	3,088	8,360	35,119	May	989	3,640	4,894	1,011	2,030	2,786
June	4,100	7,360	41,020	3,233	4,350	19,130	June	2,932	5,080	20,243	1,804	2,080	5,096
July	1,753	3,280	7,814	1,953	2,050	5,440	July	980	4,290	5,723	795	620	672
Aug.	861	16,060	18,810	1,329	27,860	50,360	Aug.	703	13,910	13,296	488	16,310	10,825
Sept.	659	16,080	14,410	640	8,430	7,336	Sept.	290	5,410	2,134	271	4,480	1,651
Oct.	1,904	30,650	79,380	894	24,750	30,100	Oct.	325	4,140	1,831	528	5,900	4,239
Nov.	953	3,320	4,310	608	1,520	1,261	Nov.	428	2,140	1,246	569	5,990	4,633
Dec.	594	850	688	490	1,610	1,070	Dec.	360	520	257	394	980	526
Total	18,796	12,500	319,562	14,347	8,410	164,003	Total	8,804	4,280	51,192	7,308	3,220	32,035
		Year 1942			Year 1948				Year 1954			Year 1960	
Jan.	430	620	364	427	590	341	Jan.	333	440	198	348	1,510	713
Feb.	435	750	442	458	3,090	1,923	Feb.	353	660	317	353	830	398
March	653	4,300	3,822	669	5,730	5,217	March	424	2,750	1,587	820	10,220	11,396
April	2,763	17,820	66,950	1,732	12,740	30,010	April	566	3,220	2,478	1,650	3,770	8,452
May	3,163	8,430	36,280	3,392	8,930	41,200	May	1,211	5,620	9,253	1,580	1,360	2,931
June	4,241	5,790	33,400	3,358	4,710	21,490	June	798	2,110	2,294	2,212	1,810	5,435
July	1,345	1,520	2,775	1,009	1,450	1,995	July	669	8,910	8,107	678	590	548
Aug.	486	1,340	887	587	11,330	9,022	Aug.	349	18,580	8,820	233	220	69
Sept.	294	740	296	242	1,330	437	Sept.	415	18,220	10,285	218	820	243
Oct.	356	1,370	665	336	2,940	1,344	Oct.	526	14,450	10,341	382	8,920	4,637
Nov.	386	690	360	434	2,200	1,310	Nov.	360	1,300	637	380	850	440
Dec.	373	560	285	365	790	394	Dec.	296	700	282	300	140	57
Total	14,925	7,220	146,526	13,009	6,480	114,683	Total	6,300	6,370	54,599	9,154	2,840	35,319
		Year 1943			Year 1949				Year 1955			Year 1961	
Jan.	347	430	202	363	2,840	1,401	Jan.	261	460	162	291	30	11
Feb.	351	640	305	374	2,960	1,508	Feb.	269	470	171	353	340	165
March	580	8,060	6,360	796	8,050	8,713	March	586	8,280	6,596	379	970	498
April	1,417	9,140	17,610	1,337	8,380	15,230	April	621	4,800	4,052	587	2,120	1,693
May	2,161	8,420	24,750	2,959	7,000	28,180	May	1,515	7,680	15,818	1,147	3,560	5,557
June	2,676	6,040	22,000	4,303	6,770	39,620	June	1,596	6,350	13,777	1,692	2,190	5,044
July	1,459	2,630	5,220	2,128	3,810	11,020	July	618	3,870	3,254	417	1,010	575
Aug.	834	7,930	9,000	632	9,850	8,466	Aug.	668	28,410	25,809	374	15,150	7,708
Sept.	494	5,460	3,670	340	3,640	1,682	Sept.	265	6,200	2,233	748	20,100	20,445
Oct.	408	5,410	3,001	521	5,530	3,919	Oct.	236	590	191	772	5,760	6,047
Nov.	477	1,850	1,199	488	980	649	Nov.	298	1,050	424	570	2,750	2,132
Dec.	420	980	560	381	330	173	Dec.	354	1,630	785	409	590	327
Total	11,624	5,940	93,877	14,622	6,060	120,561	Total	7,287	7,390	73,272	7,739	4,770	50,202
		Year 1944			Year 1950				Year 1956			Year 1962	
Jan.	298	380	156	358	380	186	Jan.	398	1,940	1,049	369	350	174
Feb.	363	670	330	414	1,020	572	Feb.	310	1,050	442	832	11,130	12,604
March	551	4,400	3,299	670	2,440	2,220	March	511	5,430	3,774	610	1,770	1,467
April	1,099	9,660	14,440	1,192	5,730	9,289	April	878	7,250	8,660	2,467	10,610	35,599
May	3,206	9,210	40,160	1,941	5,140	13,560	May	2,125	8,410	24,290	3,716	2,940	14,851
June	4,144	5,120	28,870	2,925	4,630	18,420	June	2,584	8,530	30,000	2,850	1,470	5,704
July	1,854	1,990	5,019	1,401	4,390	8,358	July	598	1,840	1,500	1,821	1,180	2,929
Aug.	456	1,000	621	444	920	555	Aug.	383	9,410	4,900	512	1,050	730
Sept.	251	390	133	343	4,030	1,880	Sept.	185	460	115	318	7,030	3,039
Oct.	362	4,430	2,183	359	1,020	499	Oct.	202	150	41	557	11,470	8,691
Nov.	401	660	359	355	300	147	Nov.	325	1,180	520	443	1,750	1,054
Dec.	345	280	133	434	410	240	Dec.	274	380	141	344	1,000	467
Total	13,330	5,280	95,703	10,836	3,790	55,926	Total	8,773	6,320	75,432	14,839	4,330	87,309
		Year 1945			Year 1951				Year 1957			Year 1963	
Jan.	356	420	205	326	210	91	Jan.	343	4,720	2,203	182	1,030	254
Feb.	381	1,970	1,021	366	410	202	Feb.	370	2,830	1,422	374	640	324
March	472	1,730	1,111	429	390	228	March	541	2,280	1,679	203	470	130
April	804	3,700	4,046	535	1,370	996	April	812	3,990	4,411	72	240	24
May	2,803	7,890	30,090	1,552	4,340	9,156	May	2,501	8,500	28,930	79	160	17
June	2,754	3,760	14,100	2,800	3,980	15,140	June	5,541	6,790	51,141	148	80	17
July	1,732	2,360	5,549	1,397	1,550	2,937	July	4,033	4,540	24,884	108	70	10
Aug.	1,071	15,550	22,650	833	11,550	13,080	Aug.	1,672	11,190	25,457	112	18,990	2,892
Sept.	334	4,080	2,184	452	9,780	6,013	Sept.	884	12,150	14,609	122	37,810	6,273
Oct.	524	7,700	5,487	425	6,150	3,554	Oct.	784	12,930	13,784	77	1,770	185
Nov.	465	950	600	466	4,060	2,570	Nov.	892	11,220	13,617	76	570	59
Dec.	359	900	441	353	950	458	Dec.	537	900	655	77	120	13
Total	12,115	5,310	87,484	9,934	4,030	54,425	Total	18,910	7,110	182,792	1,530	4,600	10,198
		Year 1946			Year 1952				Year 1958			Year 1964	
Jan.	384	500	262	593	12,090	9,752	Jan.	415	430	244	79	110	12
Feb.	333	370	166	396	970	524	Feb.	536	2,910	2,120	245	860	288
March	514	1,800	1,257	435	1,820	1,076	March	749	4,960	5,048	382	4,520	2,350
April	1,016	6,400	8,839	2,209	12,020	36,117	April	1,580	10,410	22,376	796	4,690	5,032
May	1,775	4,670	11,280	5,062	7,180	49,452	May	3,900	7,840	41,559	356	2,990	1,447
June	1,995	4,240	11,500	5,203	4,100	29,019	June	3,763	4,950	25,321	77	50	5
July	784	3,640	3,878	1,590	1,690	3,646	July	683	510	471	84	4,620	528
Aug.	567	21,400	16,500	833	4,180	4,737	Aug.	337	7,200	3,300	287	23,480	9,164
Sept.	372	11,390	5,760	596	9,350	7,581	Sept.	379	7,760	4,000	191	4,860	1,262
Oct.	419	3,910	2,227	393	810	434	Oct.	346	1,910	900	298	910	368
Nov.	492	2,000	1,340	396	410	220	Nov.	385	1,240	690	371	860	432
Dec.	468	1,430	909	400	550	301	Dec.	388	570	300	416	1,280	724
Total	9,119	5,150	63,918	18,106	5,800	142,859	Total	13,461	5,810	106,289	3,582	4,450	21,662

TABLE 44
COLORADO RIVER BASIN
HISTORICAL FLOW AND SEDIMENTATION DATA

For Colorado River near Grand Canyon, Arizona

Month	Flow (1,000 A.F.)	Weighted mean concentration (p.p.m.)	Load (1,000 tons)	Flow (1,000 A.F.)	Weighted mean concentration (p.p.m.)	Load (1,000 tons)
		Year 1965			Year 1968	
Jan.	608	3,270	2,704	658	650	578
Feb.	539	1,960	1,436	534	1,930	1,402
March	568	3,410	2,638	900	1,410	1,721
April	1,251	6,380	10,864	1,078	1,340	1,960
May	2,282	3,180	9,860	976	480	636
June	2,282	1,310	4,074	925	300	380
July	724	2,290	2,256	865	1,430	1,678
Aug.	879	1,790	2,138	775	5,980	6,298
Sept.	767	1,990	2,080	675	460	420
Oct.	675	160	144	647	1,030	909
Nov.	612	470	393	675	340	312
Dec.	586	1,370	1,091	665	210	188
Total	11,773	2,480	39,678	9,373	1,290	16,482
		Year 1966			Year	
Jan.	529	1,750	1,260			
Feb.	524	340	240			
March	718	1,520	1,488			
April	865	460	547			
May	1,011	400	557			
June	789	200	212			
July	698	180	168			
Aug.	694	230	218			
Sept.	623	910	770			
Oct.	567	870	668			
Nov.	589	30	23			
Dec.	670	2,480	2,263			
Total	8,277	750	8,414			
		Year 1967			Year	
Jan.	648	200	175			
Feb.	564	120	92			
March	704	150	147			
April	801	300	324			
May	861	200	229			
June	711	310	296			
July	693	4,800	4,519			
Aug.	786	8,310	8,882			
Sept.	713	6,500	6,304			
Oct.	459	870	545			
Nov.	495	300	200			
Dec.	597	570	463			
Total	8,032	2,030	22,176			

JAMES L. OGILVIE
Secretary-Manager

Board of Water Commissioners
144 West Colfax Avenue Denver, Colorado 80202 Phone 222-5511
COMMISSIONERS
ANDREW HORAN, JR., President WILLIAM G. TEMPLE, 1st Vice-President
JOHN A. YELENICK A. ASBORNO CHARLES F. BRANNAN

March 14, 1972

Mr. Murray Stein, Director
Enforcement Proceedings Division
Environmental Protection Agency
Crystal Mall Bldg. 2
Washington, D. C. 20460

Dear Mr. Stein:

On February 17, 1972, at the close of the Colorado River Enforcement Conference, it was announced that 30 days from that date would be allowed for interested parties to submit statements to you to be included in the official record of that hearing and conference. Therefore, we respectfully request that this letter be considered as a statement of the Board of Water Commissioners of the City and County of Denver and be included in and made a part of the record of the hearing and conference held in Las Vegas, Nevada February 15 through 17, 1972.

The Board of Water Commissioners of the City and County of Denver is charged with the responsibility of supplying water to the Denver metropolitan area for all the municipal uses associated therewith. Presently the water system created by the Board of Water Commissioners is serving nearly three-quarters of the people of the Denver metropolitan area, that is, more than 800,000 people are dependent upon this system for this most necessary commodity to sustain life. Although growth in this metropolitan area has occurred at a high rate for some years, the growth experienced in recent months has been at such a high rate that it is almost unbelievable.

At the present time more than half the people served by this system receive water diverted from the Colorado River and its tributaries. This water is transported through the various tunnels of this system from the Western Slope to the metropolitan area. Water to meet the needs of future growth of the area, must necessarily come from the Colorado River and its tributaries through the systems presently constructed or additional facilities now in the planning stages of the Board of Water Commissioners. These diversions from the Colorado River to the Eastern Slope, commonly called transmountain diversions, are accomplished under the constitution and laws pertaining to water rights of the State of Colorado. Such diversions are also recognized to be within the provisions and intent of both the Colorado River Compact and the Upper Colorado River Compact.

As a major user of waters from the Colorado River, the Board of Water Commissioners is concerned with what many consider to be a serious problem on that river, that is the salinity problem. Because of that concern, we have reviewed the report of the Environmental Protection Agency, dated 1971, entitled "The Mineral Quality Problem in the Colorado River Basin." Although numerous comments could be made regarding the content of that report, many would, no doubt, duplicate those already voiced at the hearings, and to avoid such duplicity, only the few following comments are submitted at this time.

1. In appendix A of the report, on pages 10 and 11, reference is made to the present quantities of water diverted outside the Colorado River Basin, and estimates are given regarding plans for future increases in the amount of exportation in the various states of the Colorado River Basin. The following statement is found on page 11 of that appendix:

> "The increase in out-of-basin diversions, particularly those in the Upper Basin, will result in further degradation of mineral quality in the Colorado River system unless some means are found for augmenting the basin's water supply with good quality waters."

It should be pointed out that, in Colorado the amount of water planned for exportation out of the Basin, falls within the allotted share of Colorado River water to Colorado by the Colorado River Compact and the Upper Colorado River Compact for beneficial consumptive use within the State of Colorado. In other portions of the report it is indicated that waters exported from the Basin in Colorado contain a salt load which is taken out of the Basin. If these waters were to remain in the Colorado River Basin, the salt load contained in those waters would also remain in the Basin. The waters would, at some time in the future, be used within the State in a manner which would cause them to be consumed thereby leaving the salts in the remaining flows of the Colorado River. It is also within the realm of possibility that those waters, or a portion thereof, would be used for irrigation purposes, and the return flows therefrom would, in addition to the above, contribute to the salt loading, that is, carry back to the stream additional mineral salts from the lands.

2. From Table 4, page 39 of appendix A, it is evident that the total dissolved solid concentrations during the run-off months is significantly less than during the base flow months. In Colorado, due to the priority doctrine, in most instances transmountain diversions from the Colorado River Basin occur primarily during the high run-off months and thereby have only little, if any, effect upon the flow of the river during the base flow months. The report seems to indicate that the intent is to manage the river so that the total dissolved solids concentrations will not go above a certain level during any month of the year. Table 4 seems to indicate that the base flow months would be the critical months with respect to such an intent.

3. In the Summary report, Chapter 7, under Alternatives for Management and Control of Salinity, an approach is suggested which would limit economic or water resource development that is expected to produce an increase in salt loads or stream flow depletions. Elsewhere in the report are contained lengthy discussions including estimates of the economic and other impacts of the present and increased salinity levels of the Colorado River. However, the report contains no estimates of economic and other impacts which would occur if the above approach,unrealistic as it may be, were allowed to occur. As stated earlier in this letter, this metropolitan area is growing rapidly, and its water supplies for that growth must come from the Colorado River. Curtailment of those necessary supplies is unacceptable.

4. In Table 1, page 15 of the Summary report, three percent of the salt concentration of the Colorado River at Hoover Dam is attributed to exports out of the basin in the amount of 465,000 acre feet per year. In comparison, on page 17 the following statement is made:

> "Blue Springs, located near the mouth of the Little Colorado River, contributes a salt load of about 547,000 tons per year, or approximately five percent of the annual salt burden at the Hoover Dam."

Such a comparison, pointing out that only one of the many point sources, according to the report, causes nearly double that associated with exports of water from the Basin, should cause consideration of solutions to the problem with a more realistic perspective applied to exportations from the Basin.

The resolution of the conferees of the Colorado River Basin states developed during the hearing and conference of February 15 through 17, 1972, suggests a positive approach to resolving the salinity problem, which appears to be the most logical approach at this time. We do, however, wish to emphasize the intent of paragraph 2 found on page 3 of the resolution, which is, that the Upper Basin must continue to develop its compact portion of the water. The program for controlling the salinity problem suggested in the resolution must go forward. However, in the meantime, this Board has no alternative but to provide those additional waters necessary for the growing population of this metropolitan area.

The Board of Water Commissioners of Denver recognizes the need to maintain the rivers and streams of the West in quality conditions, and is interested in this problem on the Colorado River. Therefore, this Board desires to cooperate with the Environmental Protection Agency, the Colorado River Basin states, the Bureau of Reclamation, and other agencies involved in order that efforts may be directed to resolution of the salinity problem.

Sincerely,

J. L. Ogilvie

J. L. Ogilvie, Manager

JLO/em

STATE OF UTAH DEPARTMENT OF NATURAL RESOURCES

DIVISION OF WATER RESOURCES

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JAMES G. CHRISTENSEN
Assistant Director
RAY H. ZENGER
Assistant Director

March 14, 1972

Mr. Murray Stein, Chairman
Conference in the Matter of Pollution of
the Interstate Waters of the Colorado River
U. S. Environmental Protection Agency
Office of the Administrator
Washington, D. C. 20460

Dear Mr. Stein:

The statement of Utah Division of Water Resources concerning the report on the Mineral Quality Problems in the Colorado River Basin is transmitted herewith for the record.

This statement is in agreement with that made by Lynn M. Thatcher for and in behalf of the Utah Division of Health. It is also in keeping with the intent of the resolution of the Conferees of the Colorado River Basin states at Las Vegas, Nevada, February 17, 1972.

Sincerely,

Daniel F Lawrence

Daniel F. Lawrence
Director

DFL:kb

Enclosure

STATE OF UTAH DEPARTMENT OF NATURAL RESOURCES

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March 10, 1972

The Utah Division of Water Resources is in complete agreement with the statement of the Utah Conferee in the matter of pollution of the interstate waters of the Colorado River and its tributaries, as follows:

STATEMENT OF UTAH CONFEREE AT SEVENTH SESSION OF THE CONFERENCE IN THE MATTER OF POLLUTION OF THE INTERSTATE WATERS OF THE COLORADO RIVER AND ITS TRIBUTARIES*

Las Vegas, Nevada
February 15 - 17, 1972

I want to begin by expressing thanks to the Environmental Protection Agency of the Federal Government, and its predecessors, for their accomplishment in making available the report on the Mineral Quality Problems in the Colorado River Basin. This report resulted from one of many recommendations made by the conferees, exemplifying the need for Federal resources to accomplish development of information required to set up a fair, practicable, and enforceable program for control of pollution in the Colorado River.

I must point out that while I served for a period as temporary chairman of the Colorado River Conferees during the time that an agreement was being developed for selection of water quality standards, I do not at this time have any such relationship to the group and my statement is not in any way related to any formal action by them. In fact, since the agreement on development of standards was achieved by the Conferees in 1967, no further formal action on this matter has been considered necessary, pending completion of studies under way at that time.

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*By Lynn Thatcher, Deputy Director of Health, Utah State Division of Health

The previous action of the Conferees to set standards, but to temporarily exclude specific standards on salinity, was based on the concept and acknowledgement that ultimately, when sufficient information becomes available, specific standards will be set for all essential parameters. The Mineral Quality Problems report mentioned provides part of the information needed to accomplish pollution control. Our deliberations on this report should guide us on a continued course of action toward the ultimate objective of water quality management.

The three recommendations which emerged in the final EPA report lead me to propose more specific recommendations as follows. These are in harmony with Utah's previous comments on the report.

1. A salinity policy should be adopted for the Colorado River System that will have as its objective the maintenance of salinity concentrations at or below levels presently found in the lower main stem.
2. Implementation of this salinity policy objective for the Colorado River System should be accomplished with acknowledgement that the salinity problem must be treated as a Basin-wide problem that needs to be solved to maintain Lower Basin water salinity reasonably near present levels while the

Upper Basin continues to develop its compact-apportioned water, recognizing that salinity levels may rise until control measures are made effective.

3. The adoption of numerical criteria should be deferred until the potential effectiveness of the Colorado River salinity control program is better known and because with the present level of information it is not possible to establish equitable, practicable and enforceable numerical standards.
4. The Bureau of Reclamation should be assigned the primary responsibility for investigating, planning and implementing a Basin-wide salinity control program in the Colorado River System, in order that Federal funds can be properly assigned for solution of this truly interstate problem.
5. The Environmental Protection Agency should continue its dedication to the program by consulting with and advising the Bureau of Reclamation, accelerating its on-going data collection and research efforts, and transferring funds to the Bureau of Reclamation.
6. The Office of Saline Water should contribute to the program by assisting the Bureau of Reclamation as required to appraise the practicability of applying de-salting techniques.
7. The Congress and Administration should be urged to accelerate the salinity control program, including appropriation of adequate funds.

In support of these recommendations it is pointed out that language of the Federal Act under which the Conference was called seems to lead ultimately to the concept of "remedial action" with respect to pollutants entering the River System. The proposed salinity control program by the Bureau of Reclamation certainly can be regarded as remedial action and seems to satisfy the intent of the law and also to support the concept of no numerical standards at this time because the very accomplishment of the suggested objectives of the Bureau will provide us with necessary information to establish such standards in a fair and equitable manner. It should be pointed out also that every State has been in the process of taking important remedial action since the Conference was first organized, and even before the seven states came to an agreement on the establishment of water quality standards. This consists of reviewing plans for new developments and imposing necessary controls. Without such controls, many new sources of salinity could have developed and increased the salinity problem throughout the Basin.

It must be stressed that delaying establishment of numerical salinity standards will not diminish these remedial actions, but that setting such standards with present inadequacies of knowledge could result in unsound, inequitable and unenforceable standards.

Let me also throw out the caution that the concept of singling out the salinity problem and taking action with respect to it alone, apart from other Conference activities, denies the basic fact that no part of a pollution problem can be separated from other parts. Salinity, radioactivity, heavy metals, bacteria, viruses, are all part of the pollution picture and have to be considered as an integrated whole.

Much has been said in the past about the need to augment the Conferees by bringing in representation of other resource interests in each State. This has always been recognized as a valid concept, and to my knowledge has been implemented in most cases. If the water resource groups in the various states feel they have not had adequate representation in the quality problem, certainly something must be done about it, and I, for one, would accept practical suggestions as to how the Conferees group could be properly augmented by others. I do not feel this problem has occurred in Utah, but I still would be receptive to some modified approach which satisfied all groups in all states.

Another specific subject of today's session is the stabilization of uranium tailings. This was discussed at length at the Sixth Session held in Denver July 26, 1967, and we are considering today some suggested regulations prepared by EPA.

At the Sixth Session it was agreed, among other things, that a long-range program for tailings control should be developed and that any control procedures adopted should be reasonably uniform among the Colorado River States. We believe these are still valid points, and we can generally support the proposed regulations.

I would like to close by strongly urging that this entire problem be kept in proper perspective. It is truly an interstate problem, and it is truly a water quality problem encompassing all aspects of water quality and water pollutants.

UTAH DIVISION OF WATER RESOURCES

Daniel F Lawrence

Daniel F. Lawrence, Director

Enf 3/31/72

RAYMOND R. RUMMONDS
CHAIRMAN AND COLORADO
RIVER COMMISSIONER
COACHELLA VALLEY COUNTY
WATER DISTRICT

RAYMOND E. BADGER
SAN DIEGO COUNTY
WATER AUTHORITY

JOSEPH JENSEN
THE METROPOLITAN WATER DISTRICT
OF SOUTHERN CALIFORNIA

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EXECUTIVE SECRETARY

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DEPARTMENT OF WATER AND
POWER, CITY OF LOS ANGELES

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MYRON B. HOLBURT
CHIEF ENGINEER

STATE OF CALIFORNIA

Colorado River Board of California

302 CALIFORNIA STATE BUILDING
217 WEST FIRST STREET
LOS ANGELES, CALIFORNIA 90012

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March 21, 1972

Mr. Paul DeFalco
Regional Administrator, Region IX
Environmental Protection Agency
760 Market Street
San Francisco, California 94102

Dear Mr. DeFalco:

During a regular meeting of the Colorado River Board of California held on March 15, 1972, a resolution was unanimously adopted by the Board urging that the Congress and the Federal Administration accelerate the Colorado River Basin Salinity Control Program.

A copy of the resolution is enclosed.

Very truly yours,

Raymond R. Rummonds
RAYMOND R. RUMMONDS
Chairman and Colorado
River Commissioner

enclosure

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Resolution of
COLORADO RIVER BOARD OF CALIFORNIA
March 15, 1972

WHEREAS, a joint Federal-State Colorado River water quality enforcement conference was held on February 15, 16, and 17, 1972; and

WHEREAS, representatives of the Colorado River Basin states testified at this conference in support of an acceleration in the on-going Bureau of Reclamation Colorado River Basin Salinity Control Program; and

WHEREAS, the Conferees of the Colorado River Basin States unanimously adopted a resolution, dated February 17, 1972, at this conference supporting such acceleration and, in particular, resolving that the fiscal year 1973 budgeted amount be augmented; and

WHEREAS, the sum of $1,055,000 was agreed upon by the Colorado River Basin states as the amount by which the fiscal year 1973 budget should be increased in order to permit an efficient acceleration of the Salinity Control Program; and

WHEREAS, the Federal Chairman of the conference stated that the Environmental Protection Agency believes it to be imperative that salinity control measures be accelerated in the Colorado River Basin; and

WHEREAS, the Environmental Protection Agency can materially assist in the development and implementation of salinity control measures by funding the construction of demonstration salinity control projects;

NOW, THEREFORE, BE IT RESOLVED that the Colorado River Board of California hereby urges the Congress and the Federal Administration to accelerate the Colorado River Basin Salinity Control Program by:

(1) Augmenting the Bureau of Reclamation's fiscal year 1973 budget for the program by $1,055,000; and

(2) The Environmental Protection Agency adopting and funding, as demonstration projects, the plans, now under development by the Bureau of Reclamation, for salinity reduction measures at La Verkin Springs, Grand Valley, and Paradox Valley.

State of California)
) ss.
County of Los Angeles)

I, HAROLD F. PELLEGRIN, Executive Secretary of the Colorado River Board of California, do hereby certify that the foregoing is a true copy of a resolution unanimously adopted by said Board at a Regular Meeting thereof, duly convened and held at its office in Los Angeles, California, on the 15th day of March 1972, at which a quorum of said Board was present and acting throughout.

Dated this 16th day of March 1972.

HAROLD F. PELLEGRIN
Executive Secretary

Enf. 2/29/72
el

issue
INTERESTED IN SAVING SOUTHERN UTAH'S ENVIRONMENT

POST OFFICE BOX 728
CEDAR CITY, UTAH 84720

February 14, 1972

Mr. Erwin Dickstein
Environmental Protection Agency
Suite 900, 1860 Lincoln Street
Denver, Colorado 80203

Dear Mr. Dickstein,

We are unable to send a representative to the Water Conference in Las Vegas this week, but we have an item we would like to submit for consideration.

One of our correspondents lives in Moab, Utah, and is concerned about the possible effects of certain solar evaporation ponds built immediately adjacent to the Colorado River.

He has submitted an article for publication in our periodical; we would like to excerpt the relevent portion for inclusion in your hearing record.

We will also inclose some previously published material on the project, which will more clearly identify the project, and who is involved.

Sincerely,

Lloyd Gordon
Lloyd Gordon
Executive Director

...TO COLLECT INFORMATION ABOUT OUR ENVIRONMENT
...TO MAKE THAT INFORMATION AVAILABLE TO THOSE WHO CAN DO SOMETHING

THOUGHTS OF A CONCERNED MOAB CITIZEN

by Lee Turpin

Another serious factor in this matter is the very real threat of ecological disaster in case one or more of the salt ponds were to lose its contents. National Park Service authorities, who would have to deal with such a disaster in Canyonlands National Park, Lake Powell, and other downstream areas, have written analyses concluding that the probability of "earthquake" destruction of the pond walls is low, and that in any event, the Colorado River ecology would be self-correcting.

True, earthquakes are quite unlikely in canyonlands, but uncontrollable, massive and devestating glash floods are NOT! Such unpredictable floods can and do ravage major roads, tear out bridges, toss house-sized boulders around like corks and cause massive land collapses and slippages. Those who live in Canyonlands country get regular reminders of the awesome and unpredictable power of such flash floods!

The earth-walled salt ponds, which contain hundreds of thousands of gallons of heavy brine, were built directly across an entire system of normally dry water courses. One good storm, of the kind that hits once or twice every year in the Moab vicinity, could, if it struck just to the east of the Dead Horse Point plateau, quite easily breach one or more of the ponds and dump their contents into the Colorado. And anyone who asserts that diddling with a little table-sized, scale model test set-up could "prove" the ponds resistant to such a flash flood just doesn't know the first thing about meaningful engineering research.

What would be the resultant damage to the ecology of the Colorado and its dowriver lakes in case of such a disaster? Only a lengthy scientific study by a highly trained team of ecologists could say with reasonable certainty, but the damage could very easily by heavy and long-lasting in Lake Powell. Marine ecosystems are notoriously delicate.

But one thing is very certain --- Park Service officials who arbitrarily decide that the Colorado River ecology would be in no serious danger from such a disaster, and who limit their estimates of the probability of such an event to earthquakes as a source, are being facetious at best, and blindly stupid at worst. With so much in the way of sport, recreation and various water uses dependent upon the Colorado River downstream of these unsightly, threatening salt ponds, isn't it about time someone took a really serious look at the problem, a look divorced from wishful thinking, shortsightedness and politics?

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Box K Lander, Wyoming 825

High Country News

February 15, 1972

Mr. Curtis M. Everts
Acting Regional Administrator
EPA Region IX
100 California Street
San Francisco, Calif. 94111

Dear Mr. Everts:

I wish to take this opportunity to heartily endorse the statement by the Rocky Mountain Center on Environment on "The Mineral Quality Problem in the Colorado River Basin." The referenced statement was presented at the Federal-State Enforcement Conference on the Colorado River at Las Vegas, February 15-17, 1972.

In spite of the fact that I have not read the report, I am quite familiar with problem areas in Wyoming. At the present time, I am protesting the marginal irrigation projects to be activated by the China Meadows Dam of the Bureau of Reclamation's Lyman Project in Wyoming; the taking of any more Desert Land Entries in the Soaphole Basin of Sublette County, Wyoming, and the continued high salt-sediment run-off of the Eden Project in Sweetwater County. All of these are environmental folly.

If possible I would like to obtain a copy of the report cited above. I would like to have it for reference material on the salinity problem.

Sincerely,

Tom Bell

Thomas A. Bell
Editor

TAB:mmd

cc Sen. Gale McGee
Sen. Clifford P. Hansen
Rep. Teno Roncalio
Gov. Stanley K. Hathaway

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MAR 13 [illegible] '72

ROCKY MOUNTAIN CENTER ON ENVIRONMENT
4260 East Evans Avenue · Denver, Colorado 80222 · 303/757-5439

ROMCOE

March 9, 1972

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Mr. Curtis M. Everts
Acting Regional Administrator
Environmental Protection Agency
Region IX
100 California Street
San Francisco, California 94111

Dear Mr. Everts:

The Board of Directors of the Rocky Mountain Center on Environment has voted to request that the enclosed Statement be included in the Proceedings of the Federal - State Enforcement Conference on the Colorado River, Las Vegas, Nevada, February 15-17, 1972. The Statement was entered at the Conference as a ROMCOE Staff Statement; the Board of Directors desires that the Statement represent a formal Board Statement.

Following the Statement is an Appendix reflecting added comments by Dr. Estella Leopold, a Member of the Board, as she has requested.

Sincerely yours,

ROCKY MOUNTAIN CENTER ON ENVIRONMENT

Roger P. Hansen

Roger P. Hansen
Executive Director

RPH:bb

cc: ROMCOE Board of Directors

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Statement by the
Rocky Mountain Center on Environment
on
"The Mineral Quality Problem in the Colorado River Basin"

Presented at the
Federal-State Enforcement Conference
on the Colorado River,
Las Vegas, Nevada

February 15-17, 1972

Rocky Mountain Center on Environment
4260 East Evans Avenue
Denver, Colorado 80222
303/757-5439

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The Rocky Mountain Center on Environment (ROMCOE) has reviewed the Report on "The Mineral Quality Problem in the Colorado River Basin" of 1971, and appreciates the opportunity to submit these comments for inclusion in the Conference proceedings.

ROMCOE is a private, non-profit regional environmental service center, providing a broad range of environmental assistance to government, conservation groups, industry and the general public in the eight Rocky Mountain States.

ROMCOE has recognized and been concerned about Colorado River Basin salinity for several years. The extremely rapid multiplication of the salt load in this century is another example of a stress on the ecosystem resulting from man's abuse of the principles of ecology. The basic cause of this stress is the exceeding of "carrying capacity" of the land. The efforts to manipulate natural processes, to extract more resources and biological production than the region can support within naturally-created limits is causing the collapse of an element of the ecosystem. Man in the Rocky Mountain West must learn to live within the capabilities of natural systems.

The logic of the water development syndrome, which is the first cause of the salinity problem, goes like this:

(1) Economic growth, development and population growth are vital to the future of the West.

(2) Economic growth and development depend almost entirely on development and redistribution of water supply.

(3) Increased water supply will require considerable accelerated water development and redistribution projects.

(4) Water development and redistribution will assure ever-expanding economic growth and population expansion.

(5) Expanding populations and economic growth will generate new demands for increasing water development and redistribution projects.

(6) Return to Step 1.

Manifestations of other root causes of the salinity problem are: Western water law; the false alchemy of turning land into money by liberal sprinklings of water; and accelerating growth ethic pressures for more water-related "pork barrel" projects.

Western water law evolved at relatively the same time and under the same frontier circumstances as the Mining Act of 1872. Both are in need of drastic revision. It is imperative that Western states recognize water quality control and ecological processes, as well as recreation, fish and wildlife and aesthetics, as "beneficial uses" of water resources. It is essential that priorities of appropriated uses be restructured to balance beneficial uses. It is to EPA's credit that this issue is identified in the Report; Western states can no longer duck the question.

Current water wisdom and water law generate exploding developments that turn "land into money." The massive water projects which stimulate rapid and uncontrolled growth, to the primary benefit of a small number of people and to the detriment of the general public, are not predicated upon sound principles of land use. And the creation of new land use patterns is the ultimate result of the projects. It is time to relate planning and development of water resources to proper land use planning. Federal money should no longer be used to perpetuate past mistakes which fail to recognize the inextricable relationships between water resources development and land use decisions.

Water policy which has caused the TDS problem of the Colorado Basin needs to be re-examined in a whole new perspective. Projects have been developed without a true assessment of total social costs and total social benefits. Resulting salinity is but one "disbenefit" which has been ignored in the accounting system for project justification.

In specific response to the Report, we would suggest a number of actions:

(1) There should be a moratorium, perhaps permanent, on any federal assistance or approval of diversions out of the Basin. Federal money or authorization should not be involved in any project which is part of a system resulting in such diversion. The projects mentioned in the Report are not a complete listing; for example, the Bureau of Reclamation is planning diversions from the Green to the Missouri Basin in Wyoming and Montana. The EPA Report discusses the fact that these are high-quality headwaters which will be diverted, reducing Colorado River flows but not salt loads by an equivalent amount. Additionally, most of these projects involve reservoirs, which increase evaporation losses (although such losses are small compared to Lake Mead and Lake Powell). Interbasin transfer economics often are not favorable when subject to close scrutiny, as is indicated by a recent book by Howe and Easter.

(2) An Interstate Commission should be created to address the salinity problem comprehensively. This Commission should be a State-Federal partnership. If left to their own devices, the states individually will probably never resolve the problems and achieve the necessary results in salinity control. The history of water quality control to date substantiates this thesis. Proposals for lining irrigation ditches, "flushing" salt-laden streams and building desalinization plants are piece-meal approaches that avoid the basic issues.

In fact, we are dismayed by the discussion of several of the alternatives to reduce the salinity problem. We cannot condone, at this point, any approach which perpetuates the present philosophy of treating the symptoms rather than the disease. The approach of out-basin diversions, augmentation into the basin, more storage and evaporation, and salinity control and removal may well become a technological-economic treadmill.

(3) Numerical criteria should be established. It is recognized that additional research is needed, but this should be conducted as rapidly as possible. Again, the absence of numerical standards historically has resulted in an absence of pollution control in America.

Additional new and innovative approaches should be investigated. A discharge permit program for irrigation run-off might be established. To overcome the problem of over-irrigation because of the fear of losing water rights, the federal government might acquire water rights in lieu of irrigation water payments. Such rights could then be used for the beneficial uses of quality control (although such rights might be downstream of the areas where the maximum need for ecological beneficial uses occurs).

New methods of controlling and delivering irrigation water, such as those used in Israel, should be implemented. (Water can be metered and piped to plant roots, using water with TDS concentrations of 1,000 to 2,000 ppm, apparently based on Israeli experience.) Federal monies might better be spent on approaches such as this rather than a continuation of the "conventional wisdom" methods.

ROMCOE believes that the National Environmental Policy Act's phraseology about wise stewardship and future generations must be taken seriously. Any program which does not have specific elements for control of excessive consumption must be re-examined. Any program which does not demonstrate definite means for conservation of resources is deficient. Western water use, both agricultural and municipal, at present does not conform to the intent of NEPA.

Most certainly, as mentioned in the Report, land suitability should be a major factor in assessing federally-funded projects. Irrigation of lands of high salinity or marginal agricultural productivity should not be permitted. Similarly, federally-assisted water projects for municipal and industrial use should recognize the erosion and salinity suitabilities of land proposed for development. Even though the total municipal contribution of salt load to the Colorado River is low, it is more readily susceptible to control than many natural sources.

Additional funding for research and control is in order. It is indicative of the root cause of the problem that the Bureau of Reclamation has a higher-than-usual budget for project development, which will aggravate the water quality problem. A reallocation of funds from development to research and control is in [illegible]

The study should identify future consumptive losses more accurately. Massive thermal power plants and oil shale development (with 1 1/2 to 3 barrels of water consumed per barrel of oil produced) will have significant effects.

The study should identify secondary impacts more carefully. If removal of salt from irrigated land is accomplished by flushing, additional fertilizer must be applied. This will cause a higher nitrate level in both surface and ground waters, with potential adverse effects such as lake eutrophication and methemoglobinemia. This is but one example of a potential secondary disbenefit.

The incidence of costs of salinity might be more precisely described. The Report states that the cost incidence of salinity is largely assignable to farmers. Yet the August, 1970, report by the Colorado River Board of California states that water users are continuing to make large investments in drainage facilities to maintain productivity. The costs are passed on to the consumers. The cost incidence may therefore be assignable to a broader segment of society, including low-income people to whom increased food prices are a major burden.

In institutional matters, a positive program for public participation should be identified. This Conference is but one form of participation; other types should be utilized as well.

It is noted that the study used a 5% discount rate in determining present worth of investments in salinity reduction programs. If a more realistic 10% "opportunity cost" were used as the discount rate, the investments would be much higher in present worth. This argues against the high-investment technological control alternatives and in favor of the alternative of "limited development." The latter alternative is also an appropriate approach as regards numerical criteria for salinity because the salinity vs. time curve flattens and becomes constant. Also, it conforms most closely to the use of ecological principles in planning.

The Report states that this "limited development" alternative may cause benefits to be foregone. In some cases, this may be true. However, because past benefit/cost ratios have not assessed total costs, the "benefits foregone" may well be "disbenefits foregone" in many cases. The use of a more realistic discount ratio will yield lower net dollar benefits; many past projects have been funded on the basis of an artificially low discount rate.

The alternative of limited development would reduce the difficulty of the control cost allocation question, where Upper Basin states contribute the salinity but Lower Basin states suffer the costs.

Some of the methods contemplated for control of natural diffuse sources will start another round of technological band-aids. Sealing of ground surfaces, contour ditches to pick up run-off and carry it rapidly to streams and similar methods will be quick-fixes, the secondary result of which will be disbenefits in a broad range of categories. The study team should proceed farther in identifying these secondary impacts and effects.

Alternatives involving desalinization which requires electrical power (such as distillation or electrodialysis) should be discouraged.

The Report discusses out-basin diversions in terms of helping the Colorado River quality problem. These diversions should be viewed in another way: the Colorado River salinity problem diminishes the merits of further out-basin diversions.

In summary, ROMCOE finds much to praise in the EPA Report and work. Its conclusions and recommendations merit support. ROMCOE is directly involved with only eight Rocky Mountain states, not including California. However, parochialism or regional chauvinism have no place in the problems addressed by the Report. The ecosystem knows no political boundaries. Mexico and America are not separable in terms of ecological processes, and the problem of salinity must be considered in this frame of reference.

APPENDIX

Comments by Dr. Estella Leopold
Member
Board of Directors
Rocky Mountain Center on Environment

1. The proposed Interstate Commission should be asked to compile comprehensive data on the entire mineral quality problem using technical assistance from USGS. This information should be available to the public.

2. The comments in the Statement about Israel's system should be strengthened. It should be asked that a similar system be attempted in the Colorado River Basin, that the proposed Commission should try to implement this, or that EPA should urge that USGS be funded to do this or at least to lay the groundwork for such a system.

3. Solar evaporation (black tents and collection pipe system) is used successfully in Australia, and should be investigated as a method to improve water quality before return flows enter the river. This could be the responsibility of the water user.

4. Emphasis should be given to the paragraph on page 3 of the Statement starting "Additional funding for research and control is in order." The research and control should be funded as higher priority than development of more projects, and related to the comments on the Israeli system and USGS studies.

EDUCATION · CONSERVATION

Montana Wildlife Federation

AFFILIATE OF NATIONAL WILDLIFE FEDERATION

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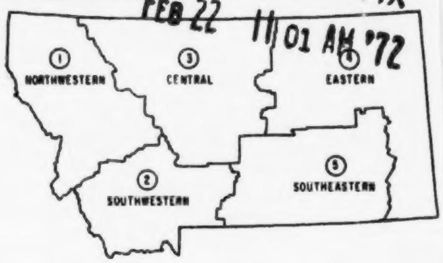


410 Woodworth Ave.
Missoula, Montana
Feb. 18, 1972

Mr. Curtis M. Everts,
Acting Regional Administrator
EPA Region IX
100 California St.
San Francisco, Calif. 94111

Dear Mr. Everts:

The EPA is to be commended for its interest in the mineral quality problem in the Colorado River Basin and for offering concerned citizens an opportunity to comment.

Unwise development and use of water for irrigation has rendered a large portion of Montana's better agricultural land almost useless. At the present time farmer, rancher and agriculturally oriented agencies are attempting to implement programs to restore these lands.

The comments prepared by the Rocky Mountain Center on Environment for the Conference on the Mineral Quality Problems of the Colorado River express the philosophy of the Montana Wildlife Federation and I would like to concur in that paper.

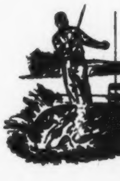
The 46 affiliated organizations spread throughout the state is composed of representation of industry, commerce, agriculture, labor and youth groups. We are dedicated to a quality environment for man and wildlife. We feel that the wise use of our basic resources, water and land, must be our primary objective.

Thank you for this opportunity to present our views. Would you please include our endorsement in the conference record?

Sincerely,

Donald Aldrich

Donald Aldrich
Executive Secretary
Montana Wildlife Federation



THE WEALTH OF THE NATION IS IN ITS NATURAL RESOURCES
CONSERVATION DOES NOT END WITH CONVERSATION

STATE OF ARIZONA
ATOMIC ENERGY COMMISSION
Commerce Building First Floor 1601 West Jefferson Street Phoenix, Arizona 85007
PHONE: (602) 271-4845

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February 17, 1972

Mr. Paul De Falco, Jr.
Regional Administrator
EPA - Region IX
100 California Street
San Francisco, CA 94111

Dear Mr. De Falco:

Your letter to Louis Kossuth, M.D., Commissioner of the Arizona State Department of Health concerning model regulations for the stabilization of radioactive tailings piles has been forwarded to this office for comment.

Enclosed, please find a copy of our critique. Copies of this information have also been made available to James Channell in Region IX, and Dr. McBride at WERL.

Thank you for this opportunity to comment.

Sincerely,

Donald C. Gilbert

Donald C. Gilbert
Executive Director

DG/cg
Encl.

MEMO

To: Donald C. Gilbert

From: Lynn FitzRandolph

Date: February 2, 1972

Re: EPA Draft Regulations for Stabilization of Tailings Piles

I have reviewed the draft regulations sent to us by Mr. Paul DeFalco Jr., Regional Administrator, EPA Region VIII, which regulations were also provided to us by Mr. E. C. Garthe of the Arizona State Department of Health. I offer the following comments:

> In the definition section on page 2, these regulations begin with the definition of "tailings pile." It is not clear from this definition whether they mean to apply these regulations to Uranium tailings piles or whether they would also apply to such activities as Copper tailings piles which contain small amounts of Uranium or other source materials. The definition talks about radioactive material in concentrations exceeding the existing background radioactivity of the surface material adjacent to the pile, but gives no numbers with regards to actual concentrations in terms of curriage per unit weight or per unit volume.
>
> Next, the definition of erosion includes the process of transporting tailings material from the pile. Of course this is not erosion and when erosion is discussed further on in the regulations, with regard to stabilization, this concept is not dealt with.
>
> Next, the definition of an active tailings pile is unrealistic. The following statement appears, "an active tailings pile will remain in an 'active' classification until the owner or assignees request in writing reclassification as an inactive pile from the Atomic Energy Commission or the Appropriate State Regulatory Agency." It is obvious that an active tailings pile is actually as defined in the previous sentence reading, "a pile either (1) currently receiving material, or (2) currently within the boundaries of an active or operating mill." This realistic definition appears to conflict with the further definition of an active tailings pile and in any event a regulation such as requiring that all piles are active until deemed otherwise, does not belong in the definitions section.
>
> On page 4 a statement of intent or policy is given. It states first of all that this regulation is intended to apply only to tailings piles defined as "inactive" by this regulation. This statement, if it is appropriate, should appear in a scope section of the regulations, that is at the beginning of the regulations and before the definitions. It would seem to be more reasonable to write regulations

for both active and inactive tailings piles, however, if they intend to apply this only to inactive tailings piles, they need to refer back to the definition of an inactive tailings pile versus an active tailings pile to figure out exactly which is which. From the definitions, one pile could be both active and inactive at the same time, and it should also be noted that no where in the regulations that follow is there a formal process for approval by the appropriate agency of transfer of status from an active to an inactive category. Further, it would seem feasible that there could be an inactive tailings pile (by a realistic definition) within the site boundaries of an active mineral mill. In such case it would seem appropriate to stabilize this inactive tailings pile. However, the definition of the inactive tailings pile does not allow for such a possibility.

The statement of intent on page 4 confuses the issue further by stating that all tailings piles containing radioactive materials are subject to this regulation on the date promulgated. The prior sentence said only that the regulations applied only to inactive tailings piles, whatever they are.

Page 5. The actual regulations, number 2, states that the State agency will determine, within six months after the effective date of the regulation, whether inactive piles in the State require additional stabilization; in such case the State is to run after the owner of the pile or previous owner, to effect stablization. In the event, such, as the Tuba City pile, where the owner has gone and abandoned the pile to the Indians, and has had the license terminated, it would appear that such a regulation would be ex=post-facto, hence Unconstitutional. There is no escape clause in this regulation as written to get around this problem.

Regulation number 4 states that new mills and reactivated mills must submit plans for stabilization of any tailings piles for review and approval. It further states that no tailings pile build up will be allowed until stabilization plans have been approved. This would appear to apply to active mills, however, the previous intent page stated that these regulations applied only to inactive piles, whatever they are.

Regulation number 7 requires the prior written approval of the agency must be obtained before any tailings pile is removed from an inactive pile. It is not clear whether this regulation is meant to apply only to licensee's or to anyone who happens to drive up to the pile with a truck. If it is the latter, this regulation would need to be put in a book seperate from our "Regulations for the Control of Ionizing Radiation," in as much as these regulations apply only to licensees and registrants. Hence, if someone were to remove material from a pile, never having had a license. for same, we could only site them for not having a license. This type of regulation as stated actually belongs in the Statues.

Regulation 8 looks good. I wrote it.

Regulation 9 speaks in terms of long-term maintenance requirements such as clean-out and repair of ditches, repair of fences, irrigation, reseeding and replanting. It would appear more appropriate to stablize a pile in such a fashion that no follow-up work is necessary.

In conclussion I think our Regulations Part I is much better and note that it has been adapted verbatim by at least one other State

Lynn Fitz Randolph 2/2/72

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JUN 16 1 41 PM '72

Sierra Club

Southern California Regional Conservation Committee

April 20, 1972

Paul DeFalco, Regional Administrator
Environment Protection Agency, Region 9
760 Market Street
San Francisco, Ca 94102

My dear Sir:

Will you please include the following statement in the record of the Hearing on Colorado River Salinity:

> Be it resolved by the Southern California Regional Conservation Committee that:
>
> 1) a salinity policy should be adopted by the U.S. Environmental Protection Agency and the States of Arizona, California, Colorado, Nevada, New Mexico, Utah and Wyoming to maintain salinity concentrations in the lower main stem of the Colorado River (below Lee's Ferry) at or below levels presently found there;
>
> 2) "numerical water quality" criteria should be adopted by the appropriate states for key points throughout the Colorado River Basin to assure that the maximum mean monthly salinity concentrations at Imperial Dam are maintained below 1000 mg/1;
>
> 3) implementation of the recommended policy and criteria should be accomplished in a basin-wide salinity control program aimed primarily at man-caused increases in the salt load. Limitation of further water resource development should be considered as one means of implementing the policy and criteria;
>
> 4) emphasis should be placed on control methods such as the following: maintaining Lake Powell at 3600' level, irrigation "scheduling" and improved agricultural practices such as use of tile drainage fields.
>
> Be it resolved, further, that the SCRCC strongly opposes any salinity control project aimed at natural resources of salinity which would result in impairment of scenic beauty in Grand

Canyon National Park, Grand Canyon National Monument or in neighboring defacto wilderness areas. In particular, SCRCC opposes any development within the canyon of the Little Colorado River to control the flow of Blue Spring. The SCRCC reaffirms its opposition to channelisation programs on the Lower Colorado River which adversely affect fish fish and wildlife habitat and the scenic values of the River.

Dated and adopted: April 15, 1972

Harriet Allen

Harriet Allen, Chairman, SCRCC
3750 El Canto Drive
Spring Valley, Ca 92077

HA/r

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